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METHODS OF STUDYING EARTHQUAKES

I PROPOSE in this paper to consider the methods of studying earthquakes of a moderate degree of intensity, *i. e.*, those which disturb areas of not more than a few thousands of square miles, and which as a rule are too weak to cause any very serious damage to property. Of such earthquakes, about ten or twelve are felt every year in Great Britian; the majority are slight, but once in four or five years a shock will occur that is noticed over a district containing more than 50,000 square miles. The methods of investigation do not, however, vary much in these cases; but, as they can only be applied with success in rather populous countries, it seems possible that they may be as useful in certain parts of the United States as they have already proved to be in the British Isles.

The whole aim of an earthquake inquiry has been widened during the last ten years. It is no longer merely a question of determining the position of the epicenter, though this is still one of the first problems to be solved. We have to ascertain not only the place where a fault-slip occurred, but the direction of the originating fault, its hade, and the nature of the movement which gave rise to the shock; for the earthquake is but a passing incident in the growth of a fault. It is the transitory effect on the surface of a displacement, within the earth's crust; and

the displacement, rather than its effect, is the more important subject for investigation.

For determining the position of the epicenter, three methods have been employed, depending respectively on observations of the direction, time of occurrence, and intensity of the shock.

The first method was suggested by Mallet, and used by him in studying the Neapolitan earthquake of 1857, and by a few other seismologists who have followed in his steps. Later on, the method fell into disrepute; and, so far as it depends on individual observations of the projection or fall of bodies, etc., it must, I think, be regarded as unreliable. But, if the number of observations be large, the average of all the records in one place may give a close approximation to the true direction. This was first shown by Professor Omori for the Tokio earthquake of 1894. In that city, the earthquake, besides a number of minor vibrations, consisted of a single great oscillation, the maximum displacement in which was $7\frac{1}{2}^{mm}$ in the direction W. 20° S. and E. 20° N. Many columns and monuments were overthrown, and especially a large number of "Ishidoro" or stone lamp-stands placed in gardens. Professor Omori measured the directions in which 245 bodies fell in different parts of the city, 144 being "Ishidoro" with circular bases. The directions are extremely varied, and at first sight appear to be subject to no law, but the mean direction given by all the observations is W. 19° S. and E. 19° N.[1] If we take only the 144 "Ishidoro" with circular bases, and regard all the determinations of the direction as of equal value, we find the mean direction to agree exactly with that given by the seismographic record, and to have a probable error of less than two degrees.

The study of the Hereford earthquake of 1896 led to a somewhat similar result. In this case, observations of overturned bodies were not available, and the estimates of the direction were all made from personal impressions. They are extremely rough, few of the observers referring to more than the eight principal points of the compass. Moreover, as a general rule, the apparent

[1] Bull. della Soc. Sismol. Ital., Vol. II, 1896, pp. 180–188.

direction of the movement was nearly perpendicular to one of the principal walls of the house in which the estimate was made. But this very fact, which seems to render the observations valueless, turns out to be of service; for the impression of direction is most distinct in buildings whose walls are perpendicular to the true direction of the shock. The majority of the records naturally come from such houses, and thus the average of all the estimates collected gives a nearly accurate result. The mean directions for London and Birmingham, for instance, intersect almost exactly in the epicenter, and those for several counties pass within a short distance of this spot.[1] Thus the method of directions, if we give a somewhat different meaning to it from that intended by Mallet, may determine the position of the epicenter with a close approach to accuracy.

It is doubtful whether the second method, depending on time-observations, can ever lead to any but very rough results. The chief reason for this is the difficulty of determining the time accurately to within a few seconds. But, supposing this were possible, there is also the uncertainty whether it is the same phase of the motion which is timed by observers in different places; for the vibrations which appear strongest to different persons do not necessarily come from the same part of the focus, and may come from parts which are separated by a distance that is considerable when compared with the dimensions of the disturbed area. While good time-observations may enable us to determine the surface velocity of the earth-wave, they can hardly, unless very numerous, afford information of much value with regard to the position of the epicenter, and still less with regard to the depth of the focus.

There remains the third, and by far the most fruitful, method of inquiry — that which is founded on the intensity of the shock.

[1] "The Hereford Earthquake of 1896" (Cornish Bros., Birmingham,) pp. 265–270. I have applied this method to the Charleston earthquake of 1886, for which Captain Dutton's well-known memoir supplies the materials. Here it was necessary to group together observations in separate states, the areas of which are to large to give good results. But, in several cases, the mean direction so obtained differs only by a few degrees from the line joining the center of the state to the epicenter.

By means of an arbitrary scale, for which we are indebted to the joint labors of Professors M. S. de Rossi and F. A. Forel, the intensity at any place may be expressed according to the mechanical effects produced by the earthquake. A series of isoseismal lines may then be drawn, each surrounding the places where the shock was of a given intensity and excluding those where it was distinctly less; and if the series is complete, the innermost isoseismal enables us to determine the position of the epicenter, generally with a close approach to accuracy.

But the method of intensities does more than this. When the isoseismal lines are carefully drawn—and this is only possible roughly elliptical in form; their longer axes are parallel or nearly so, but they are not coincident. In my report on the Hereford earthquake (pp. 216–218), it is shown that this must be the case when the earthquake is due to the friction generated by a fault-slip; for the focus is then a surface inclined to the horizon. Moreover, the focus and relative positions of the isoseismal lines are indices of the direction and slope of the fault-plane. The longer axes of the curves are parallel to the fault-line or strike of the fault; and, on the side toward which the fault slopes, the isoseismal lines are further apart than on the other side of the fault-line, except at great distances in the case of a strong earthquake, when the inequality is reversed.

I can give no better example of a slight earthquake than that which occurred on April 1, 1898, in the south of Cornwall.[1] The positions of the principal places where it was felt are shown in Fig. 1, but the coast-line is omitted in order to simplify the diagram. The continuous curves represent the isoseismal lines of intensities 4 and 3 of the Rossi-Forel scale; and their forms and relative position show that the fault-line must run from E. 33° N. to W. 33° S., and that the fault must hade to the southeast.

The latter inference is corroborated by the study of the sound-phenomena, to which the two dotted lines relate. The outer of these lines represents the boundary of the sound-area,

[1] Quart. Jour. Geol. Soc., Vol. LXVI, 1900, pp. 1–7.

while the inner one separates those places where the sound was loud from those where it was distinctly fainter. As the more prominent sound-vibrations appear to come from the upper margin of the seismic focus[1], the northwesterly shift of the sound-curves with respect to the isoseismal lines implies that the fault hades in the direction opposite to them.

One of the most interesting features of British earthquakes, though it is by no means confined to them, is the double nature of the shock. At many places there are two distinct series of vibrations separated by a brief interval of absolute rest and with a large number of observations—they are as a rule quiet. This was the case during the Hereford earthquake of 1896 nearly all over the disturbed area. As a rule, however, a weak tremor and a faint rumbling noise are observed during the interval at places near the epicenter; while at considerable distances from the origin these become imperceptible, and the shock appears to consist of two detached portions. The double shock is chiefly characteristic of strong or severe earthquakes but there are several slight ones in which it has been observed. Attempts have been made to explain it by the reflection or refraction of the earth-waves at the bounding surfaces of strata, or by the existence of longitudinal and transversal vibrations. But the wide distribution of the places where the double shock is observed and the fact that the relative nature of the two parts of the shock is not constant all over the

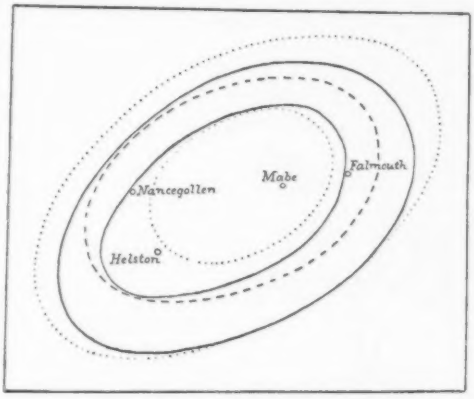

FIG. 1.

[1] Phil. Mag., Jan. 1900, pp. 66–70.

disturbed area, are conclusive against any theory based on the assumption of a single initial impulse. In the cases which have been investigated, there can be no doubt, I think, that there were two distinct foci, and that the impulses at them were nearly, but not quite, simultaneous. In the Charleston earthquake of 1886, Captain Dutton was able to locate the two foci; and this has also been done in several British earthquakes.

There appear, however, to be two distinct classes of earthquakes in which a double shock is observed; of which the Cornish earthquake of 1898 and the Hereford earthquake of 1896 may be regarded as respective types. The chief outward difference consists in the length of the interval between the two parts of the shock. In the first case, the interval was a quarter of a minute or more in length; in the second, it varied from a few seconds to zero. The Cornish earthquake consisted in reality of two successive earthquakes originating in nearly the same region of the fault, and the foci were overlapping. The Hereford earthquake was a true *twin* earthquake, the foci were completely detached; but the impulses at the two foci were due to the same initial stress, and the impulse at the second was in no way a consequence of that at the first, for it took place before the earth-wave from the first had time to reach the other.[1]

The two parts of a twin earthquake differ as a rule in intensity, in duration, in the period of their vibrations, and possibly in other ways. The distribution of the places where the first part was stronger, etc., than the second, enable us to determine at which focus the initial impulse was the more powerful and which was first in action. In the Hereford earthquake, the region in which the first part of the shock was stronger, of greater duration, and consisted of slower vibrations, was separated from that in which the same features characterized the second part, by a hyperbolic band, passing between the two foci. Within this band the

[1] The explanation of the double shock given in the report on the Hereford Earthquake (p. 295) I believe to be generally true for twin earthquakes; but I propose to consider the subject more fully in another paper.

two parts of the shock were superposed, showing that the impulses were not simultaneous, and that the focus within the concave part of the hyperbola was last in action. In the Cornish earthquake of 1898, the interval between the two parts of the shock was so great that the first and weaker part was felt all over its disturbed area before the second was felt at its epicenter. Consequently, the broken line in Fig. 1, which surrounds all the places where the double shock was observed, constitutes the boundary of the disturbed area of the earlier portion.

In studying an earthquake, there will be found on almost every point considerable conflict in the evidence collected. Much of it is no doubt due to inaccurate observation, part to a misunderstanding as to the information desired. It is in the records of the sound phenomena that the greatest diversity exists, a diversity which can hardly be ascribed to inattention or defective observation, and which can only be explained completely on the supposition that the sound is so deep that some persons are incapable of hearing it. Near the epicenter, the strength of the sound-vibrations is so great that they are audible to nearly every person, but the percentage of observers who hear the sound decreases rapidly towards the boundary of the sound-area. The variation in audibility throughout the sound-area may be illustrated by means of isacoustic lines. The percentage of auditors of the sound among those observers within a given area who felt the shock is taken to correspond to the center of the area in question, the lines joining adjacent centers are divided so as to give points where the percentage would, on the hypothesis of uniform variation, have certain definite values, say 90, 80, 70, etc., and lines are drawn through all points where the percentage marked is the same. The isacoustic lines for the Hereford earthquake of 1896 are represented in Fig. 2. The axis of the isoseismal lines runs almost exactly northwest and southeast, and the points of greatest extension of the isacoustic lines lie on a curve (broken in the figure) which coincides almost exactly with the hyperbolic band referred to above. The explanation of the peculiar distortions of the isacoustic lines is that, along this band, the

sound-vibrations from both foci were heard simultaneously, and the additional strength thus rendered them audible to an increased percentage of observers.[1]

The variation of other phenomena may be similarly represented — such as the frequency of comparison of the sound to

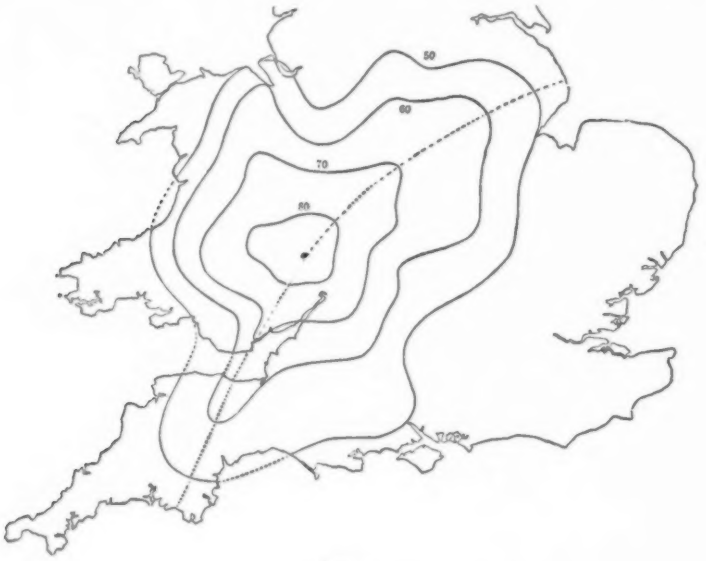

FIG. 2.

definite types, the audibility of the sound-vibrations before and after the shock is felt, the audibility of the loud crashes heard when the sound is loudest, etc. The method of course requires a very large number of records for its employment; but, in no other way, can the influence of erroneous or defective observations be so successfully eliminated.

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[1] Phil. Mag., Jan. 1900, p. 43.

GLACIAL GROOVES AND STRIAE IN SOUTHEASTERN NEBRASKA[1]

NEBRASKA is so close upon the western as well as the southern limit of the drift that evidences of glacial action which might be commonplace elsewhere are rare and interesting here. The mere fact that glacial grooves and striae have been found seems worthy therefore of mention. Glacial drift, readily recognizable as such, does not extend far west of the 97th meridian, and in but one place in the state, on the Dakota-Nebraska boundary, does it reach the 98th meridian. East of the 97th meridian it is distinct and unmistakable, and it may be offered as a safe statement that probably in no other state is the glacial drift so generally recognized as such by the mass of the people. This is due to the presence of numerous bright red and purple bowlders of Sioux quartzite. They are unmistakable, and it is generally known that they have been transported from the region of Sioux Falls in South Dakota, and scattered along the eastern border of Nebraska, and south into Kansas. Bowlders of Sioux quartzite twenty feet in diameter are to be found as far south as the Nebraska-Kansas line. A heavy mantel of drift, overlaid by a hundred feet or so of loess, so effectually conceals the rocks that exposures are rare, and striations and similar evidence of glacial action, which may be common enough in fact, are not seen. The first were found by the author in 1894 on a slab of Carboniferous limestone in the old Reed quarry one mile northeast of Weeping Water.

Though not found exactly in place it was unmistakably native rock. The ledge from which it came has just been found by Mr. E. G. Woodruff (Univ. Nebr. 1900). It is a narrow ledge perhaps 300 feet long by five to six feet wide, leveled, smoothed, and striated throughout. The grooves and striae run south eleven degrees east. One groove, the most conspicuous

[1] Paper read before the Nebraska Academy of Science, December 2, 1899.

FIG. 1.—Glaciated surface, carboniferous limestone, Weeping Water, Nebraska, badly shattered by a blast, yet plainly showing striae and grooves. The central groove varies from three to four inches in width, and is about one and one quarter inches deep, and runs south 29° west. From a photograph by the writer.

noted, being three inches across and one and a quarter deep, ran south twenty-nine degrees west. There were numerous ragged grooves varying from one quarter to one half inch in depth, and innumerable closely crowded parallel striae. The whole surface was reduced to a plane, portions of which were well polished. Upon it rested a thin layer of drift consisting of a little clay, numerous large pebbles and an occasional bowlder of Sioux

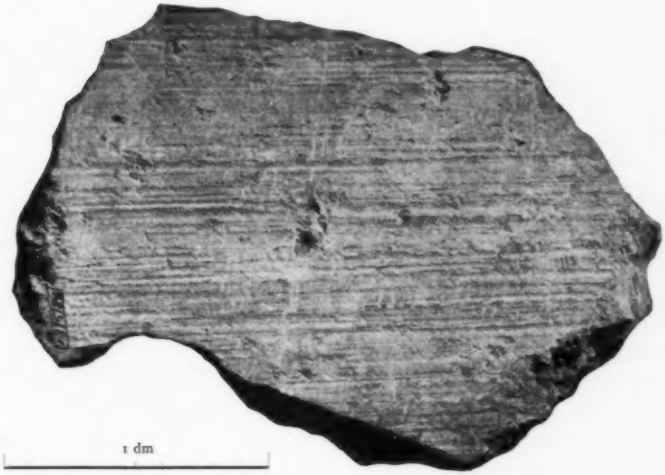

FIG. 2.—Cabinet specimen (7 by 10 in.) in the State Museum of Nebraska, showing planed surface and glacial striae on carboniferous limestone, Weeping Water, Nebraska. Striae run south 11° east. Photograph of a specimen procured by the writer in 1894.

FIG. 3.—Cabinet specimen (7 by 10 in.) in the State Museum of Nebraska, showing planed and polished surface, striae, and a small glacial groove, carboniferous limestone, Weeping Water, Nebraska. Photograph from a specimen secured by Mr. E. G. Woodruff, fall of 1899.

quartzite, the largest noted being about three feet through. The drift is thin here, nowhere exceeding a foot or two, as far as observed. Upon this thin but unmistakable layer of drift lies some twelve to fifteen feet of loess.

Two very tortuous miniature channels with polished and scored sides were noted. The curves were so abrupt that the striating and polishing must have resulted from the action of streams of glacial mud and gravel being under stress and driven with unusual force through the confined and winding channel.

This seems to be the point farthest south in the state where such grooves and striae have been noted. At La Platte light grooves and striae have been reported in the Carboniferous limestone. In the Dakota Cretaceous near South Bend, Mr. Charles N. Gould has observed parallel grooves which may be glacial, or as he thinks more likely artificial, being made by the Indians in former times when sharpening implements in the sandy rock of this formation. In the spring a considerable area at Weeping Water will be stripped of the overlying drift and loess, at which time it can be examined to much greater advantage than now.

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A NOTICE OF A NEW AREA OF DEVONIAN ROCKS IN WISCONSIN

THERE is an outcrop of Devonian rock on the shore of Lake Michigan in this state, ten miles north of Port Washington and about a mile southeast of the little village of Lake Church, which has hitherto escaped the notice of geologists. The discovery of this exposure by the writer in the summer of 1896 was somewhat of a surprise as all the nearest outcrops of rock, to the north, south, and west, belong to the Niagara formation. In the neighborhood of Lake Church the heavy drift deposits, which form high bluffs on the very edge of the lake at Milwaukee and at Port Washington, recede quite a distance from the shore and take the form of a series of rolling ridges which increase in height towards the west. Between the lowest of these ridges and the lake there stretches a sort of terrace, elevated only five or six feet above the lake level at its eastern margin and rising very gradually as it recedes from the shore. The rock in question forms the floor of this terrace and crops out in various places in the neighborhood upon the beach and under the water. It is also uncovered in the bed of a little watercourse which traverses the terrace. The strata are nearly level but probably dip slightly towards the east. The rock is an impure limestone, somewhat earthy in composition and somewhat granular or sandy to the touch. An inconsiderable excavation has been made in it by the owners, disclosing a thickness of about six feet of Devonian strata, beneath which is a transition layer of bluish shaly rock, resting on a very hard, white, crystalline limestone which probably belongs to the Niagara.

About sixty species of fossils have been obtained from the upper layers, all of which, with the exception of a single fragmentary dental plate of Rhynchodus, are in the form of casts and impressions, a fact which renders their determination a matter of some difficulty. The fauna comprises about twenty-four

species of brachiopods, twelve or thirteen of gastropods, nine corals and half a dozen pelecypods. *Orthoceras*, *Rhynchodus*, and *Proëtus* are each represented by a single species; there are scattered crinoid joints and a few other species whose generic relations, even, have not yet been satisfactorily determined.

Among the most abundant species are: *Chonetes scitulus* Hall, *Stropheodonata nacrea* Hall, *Atrypa reticularis* L. and a species of *Spirifer* with a marked depression in the fold of the brachial and a remarkably broad and strongly impressed muscular area in the pedicle valve. Two or three other species, both of *Spirifer* and of *Stropheodonta*, are apparently represented. *Stropheodonta demissa* Conrad is probably one of the latter; another is a strongly arcuate form, with a thick shell and an almost smooth surface. Among other species which have been identified are *Cyrtina hamiltonensis* Hall (rare), *Orthis impressa* Hall (a single specimen), *Atrypa spinosa* Hall, *Productella spinulicosta* Hall, and *Conocardium cuneus* Conrad (the three last fairly common). There is also a species of *Athyris;* one of *Meristella;* a *Cyclonema*, near *C. multilira* Hall; two species of *Loxonema* of ordinary form; a tapering *Turritella*-shaped shell, with both revolving and transverse striae, resembling but not identical with certain forms occurring in the Devonian of Manitoba and referred by Whiteaves to the genus *Loxonema;* a *Murchisonia*, near *M. turbinata* Schlotheim; a *Trochonema*-like shell with strongly angular and nodose revolving ridges; a *Bellerophon*, near *B. pelops* Hall or *B. newberryi* Meek; a *Paracyclas* and a *Mytilarca*. Among corals are a species of *Streptelasma;* one of *Zaphrentis;* one of *Acervularia* and another of an allied genus; and a species of *Favosites*.

The rock in which this fauna has been discovered is thought to constitute good material for road-making. A more extensive development of the quarry, which it is hoped will take place before long, will furnish opportunities for more satisfactory investigation of the fossils.

CHARLES E. MONROE.

MILWAUKEE, WIS.,
April 25, 1900.

KINDERHOOK STRATIGRAPHY

At frequent intervals during the past decade, there have appeared notes on certain beds, occurring in different parts of the Mississippi valley, which have passed under the general name of Kinderhook. For the most part these notes have dealt with local phenomena. In the present connection attention is called briefly to some problems of broader significance.

Along the upper Mississippi River the formations immediately underlying the great Burlington limestones are exposed chiefly in two localities. One is at Burlington, Iowa, and the other at Louisiana and Hannibal, Missouri, and at Kinderhook, Illinois, which is only a few miles from the last named place. Between the two localities the distance is 125 miles. In this distance a shallow syncline carries down the Kinderhook beds 200 feet below the level of the stream.

The early investigations of this Burlington-Louisiana section were carried on simultaneously at the two ends, but by different persons. When the time came to parallel in detail the vertical sections at the extremes difficulties arose. The various beds could not be traced from one point to another because, for most of the distance, the strata were not open to inspection. The method of correlation by visible continuity was inapplicable. Comparison by similar lithologic sequence was likewise unsatisfactory, because the sections were so very different, and it was impossible to tell when or in what manner the changes took place.

When the fossils of the two localities were compared, the results were singularly futile, so far as throwing light upon the problem of exact stratigraphic equivalency. The organic forms were unequally distributed. A large part of both sections had yielded no fossil remains at all. In the northern locality the known animal remains had been found chiefly at the very top

of the section; in the southern, at the very bottom. As to the exact horizons of their occurrence the literature usually gave small clew. With most of the forms no comparison was possible, for the facies of the two faunas were of very different types. After an elapse of 30 years the question of the geological age of the various beds presented itself as formidably as when first these rocks were brought into notice.

Of late years a number of deep wells have been drilled along the upper Mississippi River. These have enabled various geological sections exposed at points far removed from one another to be connected with a degree of confidence never before attained. In the Louisiana-Burlington cross-section, wells at Hannibal, La Grange, Keokuk, Burlington and other points have disclosed important features. These purely stratigraphical features are of particular interest at the present time because of their bearing upon the lack of geological integrity of the typical Kinderhook.

On all of the problems mentioned, the data derived from the deep-well sections have an important bearing. Furthermore, it is pointed out just along what lines critical evidence is to be sought.

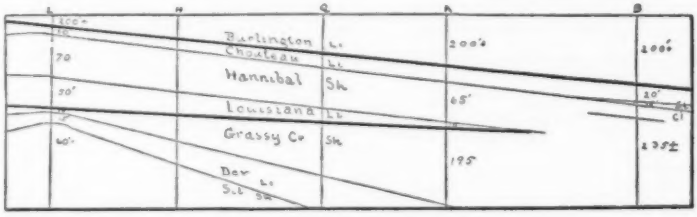
A few years ago the geological sections at the type localities of the several parts making up the Mississippian series of the Carboniferous, were personally studied in order to find out from first hands just what each really meant.[1] Among these sections were those found in the vicinity of Kinderhook, Illinois, which were the basis of what had been long considered the lowermost member of the Carboniferous system, and had been widely known as the Kinderhook formation. Hannibal and Louisiana, Missouri, which are not far away, exhibited the same rocks even to better advantage, and therefore were regarded in all respects as essentially typical.

As is well known, the typical Kinderhook has been regarded as consisting of three members: A basal Louisiana limestone, a median Hannibal shale, and a capping Chouteau limestone.

[1] Principal Mississippian Section; Bull. Geol. Soc. America, Vol. III, pp. 283–300, 1892.

These three members retain their lithological characteristics over broad areas, the extent of which is surprising. The distances of continuity are so great that ordinarily doubt would be cast upon this assumption were it not for the fact that all observations are easily checked by the overlying Burlington limestone. While the lithological features of the several parts of the Kinderhook are so persistent, the faunas contained appear to be remarkably local in nature. The existence of a large number of restricted faunas, in place of a general one is probably the chief cause for past failures to correlate, by the biotic method, the various sections of the Kinderhook.

The stratigraphical relationships of the Burlington and Louisiana sections at last appear to be indicated by the aid of the deep wells drilled between the two points. These relationships are best expressed by the following diagrammatic cross-section, in which, however, while drawn to a scale, no allowance is made



for the synclinal attitude of the strata. What has been regarded as the typical Kinderhook formation is included between the heavy lines.

Immediately beneath the Louisiana limestone, the basal member of the Kinderhook at Louisiana and vicinity, is the Black shale of the Devonian, according to Meek and Worthen.[1] In the neighborhood of Louisiana it has been called the Grassy Creek shale.[2] While at the town itself it only has a thickness of about six feet, and thins out completely to the south, it is 30 feet thick on Grassy Creek, a few miles to the west. Northward,

[1] American Jour. Sci. (II), Vol. XXXII, p. 228, 1861.

[2] Proc. Iowa Acad. Sci., Vol. V, p. 63, 1898.

this shale bed grows rapidly in thickness, until at Keokuk it reaches 195 feet.

The Louisiana limestone, which is over 50 feet thick at the type locality, appears to get thinner northward. At Keokuk it is only 10 feet in thickness, and seemingly fails altogether before Burlington is reached. Its southern extension is not known. It is not believed to be as extensive as Missouri geologists have generally supposed. The Lithographic limestone of southwestern Missouri is not thought to be the same. The apparent fading out towards the north is not an unusual phenomenon among the limestones of the region. Similar cases are known in the Missourian series, or Upper Coal Measures, farther west.[1]

At Louisiana and Hannibal, the shales bearing the latter name have a thickness of about 70 feet. This thickness is maintained northward at least as far as Keokuk, as deep wells show. Beyond this point at Burlington a very similar shale, appears in the base of the river bluffs, having a thickness, including the upper sandy portion (Chonopectus sandstone of Weller[2]), of 85 feet, above the river level. Shale is known to extend downward at least 150 feet more, making a total measurement, from the top of the Chonopectus sandstone, of 235 feet.

The question has arisen as to how much of the Burlington section[3] can be regarded as representing the Hannibal shale. On fancied lithologic grounds solely it was early suggested by Worthen[4] and White[5] that the earthy fragmentary limestone, 15 to 18 feet thick, overlying the lower "yellow sandstone" (the Chonopectus bed) was the northern extention of the lithographic (Louisiana) limestone of Missouri. This view has been recently again alluded to by Weller.[6] If this were the case all

[1] Proc. Iowa Acad. Sci., Vol. VII, 1900.

[2] Trans. Acad. Sci., St.Louis, Vol. X, p. 57, 1900.

[3] Full detailed descriptions of the various sections here referred to will be found in the lately issued volumes of the Iowa and Missouri geological surveys.

[4] Geology Iowa, Vol. I, p. 206, 1858.

[5] Boston Jour. Nat. Hist., Vol. VII, p. 212, 1860.

[6] Trans. Acad. Sci., St. Louis, Vol. X, p. 123 1900.

of the Burlington section below the top of the Chonopectus sandstone would be beneath the horizon of the Louisiana limestone.[1]

In the recent Iowa[2] and Missouri[3] reports the basal shale as exposed above river level at Burlington was considered as about the equivalent of the Hannibal shale. At the same time it was surmised that this part of the section at Burlington probably rested directly upon certain shales found farther north, and which were commonly regarded as belonging to the Devonian. This, however, was merely a working hypothesis; and opportunity did not present itself to carry out very far the necessary field investigation to either prove or disprove it.

On this supposition the 235 feet of shale, of which about one third is above the river level at Burlington, would represent not only the Hannibal shale, but in its lower unexposed part, a so-called Devonian shale as well. The recent discovery of a rich fauna[4] considered as composed of typical Devonian types gives strength to this idea. Still later Weller[5] gives expression to something of the same conception when he states regarding the occurrence of the Hannibal shales in Iowa, that it is "probable that the section at Burlington is equivalent, or more than equivalent, to the whole of the section as known in Missouri." If we take into consideration the 150 feet of shales below water level the stratigraphic evidence now presented goes far towards proving the statement.

The deep-well sections give no indication that the Hannibal shales, as they are known at the type locality, change materially either stratigraphically or lithologically from Louisiana to Keokuk. There is yet no reason whatever for imagining that they should abruptly thin out entirely between Keokuk and Burlington.

[1] Iowa Geol. Sur., Vol. X, p. 79, 1900.

[2] Iowa Geol. Surv., Vol. I, p. 55, 1893.

[3] Missouri Geol. Surv., Vol. IV, p. 56, 1894.

[4] Proc. Iowa Acad. Sci., Vol. IV, p. 39. 1897.

[5] Trans. Acad. Sci., St. Louis, Vol. X, p. 123, 1900.

One the other hand, all evidence goes to show that the Louisiana limestone gradually becomes thinner as the distance increases from the type locality northward, until at Keokuk it is less than one fifth of its original thickness. Everything indicates that it has faded out completely long before the city of Burlington is reached. If the Hannibal shales have retained anything of their normal thickness, as they have in the long distance from Louisiana to Keokuk, the horizon of the Louisiana limestone would be expected to be not far above the river level at Burlington. No bed at or near this horizon has been found that would correspond in lithological or any other of the characters of the Louisiana formation. The only layer of the whole Burlington section below the base of the Burlington limestone, that at all resembles the Louisiana is the Productal limestone (No. 3 of Keyes, No. 4 of Weller), with a coralline zone at the base (No. 3 of Weller), and overlying the Chonopectus sandstone. The lithologial characters of the two are only remotedly related. There are strong stratigraphic reasons, however, for connecting this stratum, as well as those above it, up to the Burlington limestone, with the Kinderhook limestones still farther north at LeGrand, in Marshall county, Iowa. Still other grounds exist for believing the Productal zone at Burlington to be the attenuated margin of LeGrand beds.[1]

All the stratigraphic evidence, as disclosed by the Mississippi River cross-section, the deep wells along the course, and the general geological features of the region appear to indicate, beyond much doubt, that the Louisiana limestone actually does become attenuated northward from the type locality, and that the underlying Grassy Creek shales and the overlying Hannibal shales merge north of Keokuk. If this be the correct interpretation, the section at Burlington, below the top of the Chonopectus sandstone, including over 100 feet of shales beneath the river level, represents considerably more than the Hannibal shales of Missouri.

[1] There is, therefore, apparently little possibility of the Productal limestone representing anything other than the Chouteau beds as exposed farther south.

The Chouteau limestone, which finds its typical development in central Missouri, appears to be well represented, in the northeastern part of the state where the typical Kinderhook is shown, by 10 feet or more of massive earthy limestone, that is fine grained and contains comparatively few fossils. It is sufficiently distinctive in lithological characters to be readily recognizable in deep-well drillings. At Keokuk, it is over 20 feet thick, and at Burlington, if we consider the interval between the Chonopectus sandstone and the Burlington limestone as representing it, about 30 feet thick. In central Iowa it is believed to be represented by the LeGrand limestone, and is over 100 feet thick, there being about the same development as in central Missouri.

The lithologic features at Burlington, while differing from those farther south and at the type locality in central Missouri, correspond very closely with the characters presented northward. At Burlington, also, it is still chiefly limestone. Here it consists of a thin basal coralline zone, the Productal limestone, the Spirifer sandstone, the Gyroceras oolite and the brown Rhodocrinus limestone. These, however, are local collectors' names, and it is not known how far these distinctions should be really recognized.

Independent of the purely stratigraphical characters of the Kinderhook, as exposed along the Mississippi River, there are certain faunal features of the formation that are not without interest. Until now, all correlations of the Kinderhook beds have had to be inferred from imperfect fossil data. Moreover, the information has been so inexact for present requirements, that the fossils have to be studied largely anew in order to find out in just what layers the various forms occur. Only in this way can useful and exact comparisons of the faunas be made.

Already Weller has begun, along the lines indicated, a series of "Kinderhook Faunal Studies." Judging from the two installments already issued it is expected that there will soon be available much of the long desired information concerning the exact stratigraphic range of the fossils, and the relationships of the various biotic groups.

CHARLES R. KEYES.

ON THE PROBABLE OCCURRENCE OF A LARGE AREA OF NEPHELINE-BEARING ROCKS ON THE NORTHEAST COAST OF LAKE SUPERIOR

In a recent paper in this JOURNAL,[1] Dr. Coleman has described, under the name of *Heronite*, an interesting analcite-bearing rock from near Heron Bay, on the northeast shore of Lake Superior, and states that although the occurrence of a dike rock of this composition would indicate the presence of nepheline syenite in the vicinity, no area of this rock had as yet been discovered in that district. Many years ago, while looking over some of the rock collections in the museum of the Canadian Geological Survey, at Ottawa, my attention was attracted by two specimens of a rather coarse-grained, red rock from Peninsula Harbor, Lake Superior, on account of the fact that their appearance suggested that they might belong to the class of nepheline syenites. Sections were made and examined at the time, but no nepheline was found, and the investigation was not carried further owing to lack of material and absence of information as to the exact mode of occurrence of the rock in question.

In connection with Dr. Coleman's paper, however, it may be well at this time to present a few notes concerning these rocks, as they indicate that the district in question affords a field of much interest for petrographical study.

The first of the rocks in question was collected by Dr. Selwyn in 1882, and is labeled "Peninsula Harbor," while the second was collected by Mr. Peter McKellar in 1870, and is labeled "Mount Point, S.E. side, Peninsula Harbor." They both come, therefore, from the same neighborhood, and probably from the same mass. Unfortunately, the specimens cannot at present be found, so that it is necessary to base the descriptions on the four thin sections in my collection.

[1] JOUR. GEOL., Vol. VII, No. 5.

The first of these rocks belongs to the class of the augite-syenites, but is of a peculiar type. The augite is represented by two varieties which pass into one another. One is a purplish-brown augite, which frequently constitutes the inner portion of large individuals, and shades away into an outer border of green augite of the second variety. This green augite also occurs in separate individuals. Both varieties have high extinction angles, and the green variety is probably an aegerine-augite. In addition to the augite, a small amount of deep bluish-green and highly pleochroic hornblende is present. The single section of this rock also contains a considerable amount of a mineral which has the high index of refraction and high double refraction of olivine, and which is destroyed by acid with gelatinization.

The feldspars, which with the augites make up most of the rock, consist in part of orthoclase and in part of microperthite, and possibly anorthoclase, and usually possess a zonal structure, an outer border or rim of microperthite often surrounding an individual of orthoclase nearly free from intergrowths. Small quantities of pyrite and magnetite are also present, as also of a deep brown, almost opaque, non-metallic mineral, which is unattacked, even by prolonged treatment, with concentrated hydrochloric acid, and which is probably one of the rarer rock-making minerals.

The structure of the rock is remarkable, and entirely different from that of the ordinary augite-syenites. The feldspars are idiomorphic, and impress their form on the dark constituents, with the exception of the olivine. These latter occupy the interstitial spaces, and are penetrated by the feldspar laths in a manner suggestive of an ophitic structure. The character of the augite and hornblende, as well as the abundance of the feldspar, suggest a magma rich in alkalis.

The second specimen strongly resembles the first, but in it the hornblende replaces the augite, and is present in large amount. This hornblende is so intensely colored that in many cases it is nearly or quite opaque, but when transparent has a deep

bluish-green color and a marked pleochroism. It has a small axial angle, and resembles in general character the variety rich in ferrous iron and alkalis described from the nepheline syenites of Dungannon, Ontario, under the name of *Hastingsite*.

The feldspars resemble those of the other specimen, but there is proportionally more microperthite and a considerable amount of an acid plagioclase. Fluor spar is also present, in not inconsiderable amount, in the form of large, colorless grains.

The structure is the same as that of the former specimen, the feldspars being idiomorphic, and the dark constituents occupying the spaces between the feldspar laths.

The specimens, therefore, while not actually containing any nepheline, have the character of certain differentiation products of alkali-rich magmas, which are found associated with nepheline syenites and other nepheline-bearing rocks in other parts of the world.

In the Report of the Geological Survey of Canada for 1846-7, Sir William Logan, after describing certain "traps" of this same district, refers to what is apparently the same occurrence, as follows:

"The rock above and below is composed of brownish feldspar and black hornblende . . . . it is large-grained, and the general mass of the country constituting the Old Pic Point and Island appears to be composed of it. Fluor spar occurs as a disseminated mineral in some of the beds. Judging from fragments on the shore, there are some beds composed of white feldspar and occasional groups of orange red grains of elaeolite, the whole studded with brilliant black crystals of hornblende, forming a very beautiful rock. The general mass of these volcanic overflows weathers to a red, and from a distance may be readily mistaken for the gneiss which underlies the chloritic shales."

Although the rocks in question are here classed as belonging to the traps of the district, in the Geology of Canada published by the Geological Survey of Canada in 1863, they are, in a reproduction of the passage quoted above, referred to simply

as "igneous rocks" and nothing is said about their supposed volcanic affinities. In the same publication also, p. 467, the occurrence is referred to as follows:

"On the main shore of Lake Superior, nearly north of the western extremity of Pic Island, is a mass of syenitic rock, composed of red feldspar and hornblende, with zircons which resemble the zircon syenite of Norway." As is well known, this latter rock is an augite-syenite, which in Norway is intimately related to nepheline-syenite.

As all the localities mentioned in this note are near one another on the same stretch of coast, and in the vicinity of Heron Bay, it seems certain that there is in this district a large intrusion of an alkali-rich magma, differentiated into various rock facies, among which there are some containing nepheline and some free from that mineral, and that Dr. Coleman's Heronite is connected with the intrusion in question.

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A NOTE ON THE LAST STAGE OF THE ICE AGE IN CENTRAL SCANDINAVIA

In the Dovre region which lies to the north of Christiania the main divide runs in an east-westerly direction. On the mountain plateaus of this region the parent rock of much of the drift is found on the southern side of the divide; consequently the ice had its movement upstream, at least during part of the ice age.

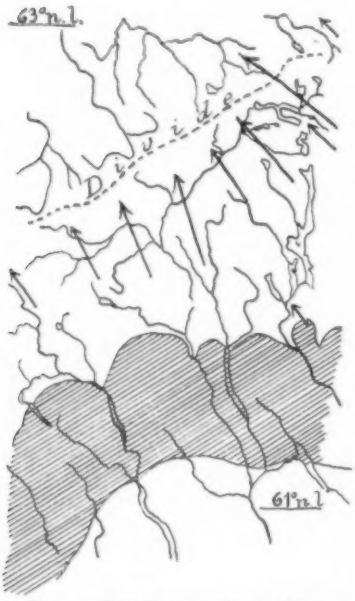

FIG. 1.—The Dovre region in Norway. The arrows mark the movement of the ice. The shaded part is the last remnant of the great ice according to Dr. Andre M. Hansen.

Dr. Andre M. Hansen has given a reasonable explanation of this fact which may be illustrated by the following diagram, Fig. 2.

The country is steeper on the north side of the divide (*a n*) than on the south side (*a s*). The contour of the ice-cover, on the other hand, formed a rather regular curve, and the movement in it took place from the thickest and highest part (*b*) outward to both sides. Consequently on the stretch (*c a*) the movement was against the slope of the surface as indicated by the largest arrow of the diagram.

Now let us leave for a moment this question of the ice movement and turn to another phenomenon. In the upper parts of the valleys to the south of the divide, strand-lines occur of the same kind as the much discussed "parallel roads"

of the Scottish Highlands. The explanation is the same in Norway as in Scotland; they are the beaches of lakes which were dammed in by ice during the late glacial time. Dr. Hansen has tried to give an elaborate account of the manner in which this came about. He thinks that the ice melted latest where the thickness was greatest, and that the last remnants came to lie as a narrow strip of ice, a sort of "ice sausage," on the slope of the south of the divide and somewhat parallel to it (see Fig. 1). On the diagram the shaded part shows the ice in the last stage, and the lakes were dammed in between it and the divide. The readers of this JOURNAL may remember that this

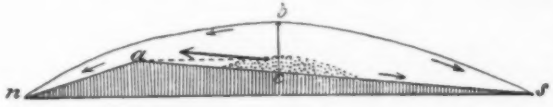

FIG. 2.

explanation was hinted at in a paper by Dr. Hansen, entitled "Glacial Succession in Norway," Vol. II, 1894, p. 137, conclusions, by the way, to which most Norwegian geologists assent only to a limited extent.

By his explanation Dr. Hansen has made urgent the question at what place the last remnants of the inland ice were located. Mr. Schiötz, professor of physics at the University of Christiania, has criticised Mr. Hansen's views from the physical standpoint in a paper entitled "How will the ice divide act during the melting of the inland ice?" printed (in Norwegian) in *Nyt Magazin for Naturvidenskaberne*, Vol. 34, Chr., 1895, pp. 102–111. He demonstrates that any "ice sausage" on the slope below the divide can come into existence only in the case that the melting takes place so suddenly and quickly that the snow line during the period of melting is at a greater height than the crest of the country. If the snow line rises gradually as the temperature rises, the diminishing glaciers will concentrate at the divide. He thinks this the most probable case, and points to the great local glaciers which undoubtedly have descended from the

divide, and to the fact that small local glaciers still exist in the region described. If Mr. Hansen is right, the snow line was first very much elevated, then descended below its present limit, and more recently has ascended again to produce the present conditions.

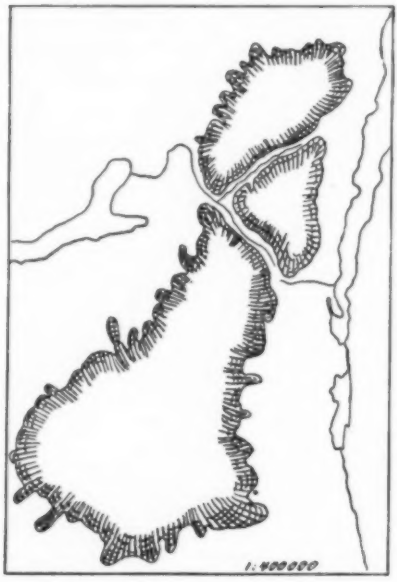

FIG. 3.—The Folgefonn glacier-field.

It seems to the present writer that a study of the now existing Scandinavian glaciers makes another explanation of the ice-dammed lakes more probable than that set forth by Dr. Hansen. It may be remembered that the region in question is to be regarded as a high plateau intersected by valleys. Our chief existing glaciers are also found in country of the same kind, and in accordance therewith they present themselves as gently-domed or shield-like snow-fields, intersected by valleys free of snow. This has long been known of the two great snow-fields of southern Norway, "The Folgefonn" and "The Justedalsbrae." The Folgefonn, for instance, is dissected by valleys into three parts, as seen on the accompanying map. In size the Folgefonn is the second among the Scandinavian glaciers. The greatest is the Justedalsbrae. Next to this comes "The Svartisen" (Svart = swarthy, blackish; isen = ice) situated under the polar circle. Even on our latest maps this glacier has been delineated as an unbroken elliptical snow-field with its greatest dimensions from south to north, although Mr. Rekstad of the Norwegian Geological Survey had shown in 1891 that the snow-field is divided

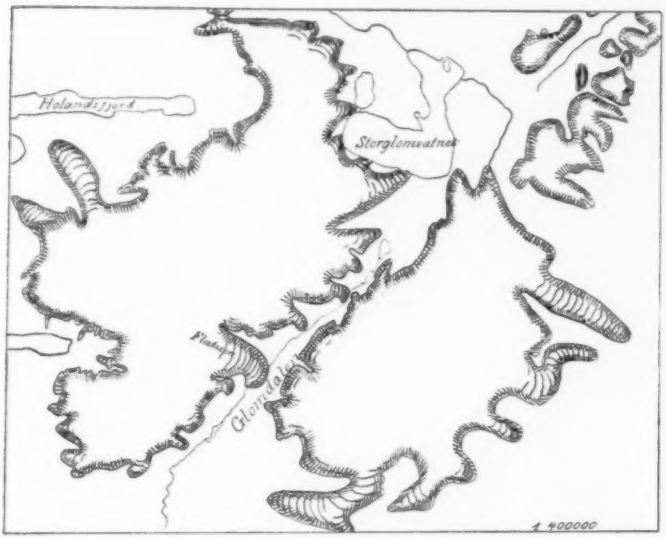

FIG. 4.—The Glacier of Svartisen.

FIG. 5.—Glaciers descending from the Svartisen to the Glomdal valley.

into two by a desert valley, the Glomdal (dal = valley). He was the first Norwegian known to have entered the inner part of that valley formerly known only to a few Laps, an incident which indicates that geographical discoveries may yet be made within Europe itself. He has described and photographed the principal

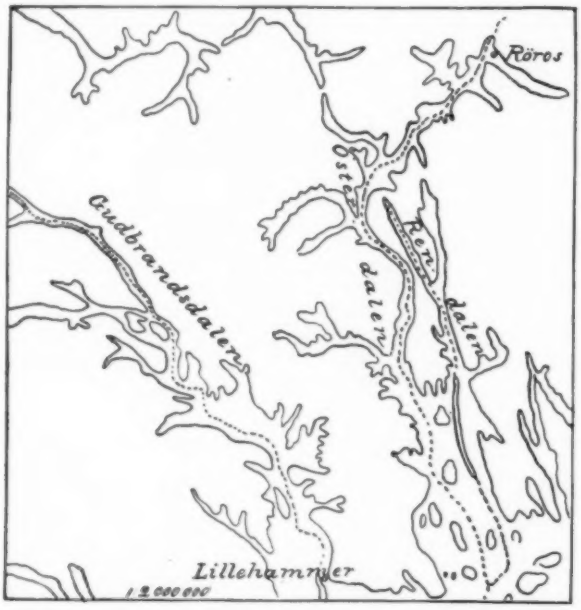

FIG. 6.—The region in the vicinity of the main Scandinavian divide to the north of Christiania. The line of 100 meters above the sea is shown.

glaciers descending into the Glomdal. The greatest is presented herewith. The Norwegian Topographical Survey has of late made a more detailed map of the region. With the aid of their material, which has not as yet been published, the present sketch map was made, Fig. 4.

If we now turn to the region of the old ice-dammed lakes, we find a country well fitted for similar extensive fields of ice and snow, with empty valleys between. The map (Fig. 6)

shows how the line of 100 meters encompasses narrow branching valleys. We may easily imagine that during a certain stage of the melting this line was the snow line and determined the extension of the snow-fields. Some glacier descending from one of the greater side-valleys may have stopped back the water of the main valley and formed a lake. Mr. Rekstad says that the river that issues from the Glomdal valley sometimes

FIG. 7.—The Daemmevand (dammed lake) in Hardanger.

rises enormously, and that the flood is probably due to the fact that the water is temporarily obstructed by the chief glacier that intrudes upon the valley. Norway has its Märjelen See corresponding to the famous Swiss lake as is well known among geologists through Lyell's Principles. The Norwegian glacier-dammed lake is the Daemmevand (the blocked-up lake) in the province of Hardanger, in the high region to the east of the town of Bergen. From an extensive snow-field, the "Hardanger jökul" (jökul = glacier) descends to a lake. On its way it blocks up the "Daemmevand." This lake has of late attracted some attention, as the water sometimes breaks through the glacier and causes sudden and destructive floods. To prevent this the government has made a tunnel about 300 meters long

through a spur of the mountain called Turumeten. This tunnel has had the effect desired in preventing the lake rising above a fixed level. Mr. A. Holmsen, who had the supervision of the work, has had the kindness to communicate a sketch-map (Fig. 7) of the surroundings of the lake, and a photograph of the blockading glacier with a part of the lake in the foreground.

FIG. 8.—The ice barrier in front of the lake Daemme, sketched from a photograph.

From a dam like this we may mentally reconstruct a barrier capable of accounting for the lakes dammed back in olden time in the Dovre region.

There are two English accounts of this lake, viz., that of Mockler-Ferrymann ("The Daemmevand of Rembesdals Glacier Lake, *Geogr. Jour.*, IV, Dec. 1894, London, pp. 524–528) and that of Munro ("On a Remarkable Glacier Lake formed by a branch of the Hardanger-Jökul, near Eidjford, Norway, *Proc. of the Roy. Soc. of Edinburgh, Session 1892–3*, Vol. XX, pp. 53–82). The two Norwegian scientists, Bing and Öyen have also made reports on the lake.

HANS REUSCH.

Studies for Students

THE PROPERTIES OF BUILDING STONES AND METHODS OF DETERMINING THEIR VALUE. II.

In selecting a stone for building or other economic purposes, one should be familiar with the

I. Color.

II. Composition, { Mineralogical, Chemical.

III. Strength, { Crushing, Transverse.

IV. Hardness.

V. Elasticity.

VI. Porosity (including fissile planes).

VII. Specific gravity.

VIII. Weight per cubic foot.

IX. Effect of temperature changes.

(*a*) Freezing and thawing of interstitial water.

(*b*) Effect of extreme heat.

X. Effect of gases, { Carbonic, Sulphurous.

XI. Quarry conditions.

There are three important methods of obtaining these facts: (1) observations at the quarry and adjacent natural exposures; (2) examination of buildings, monuments, or other constructions built out of the stone; (3) laboratory examination. If a geologist were obliged to choose between the three, he would probably consider the first method most satisfactory. The architect and builder, on the other hand, would undoubtedly choose to examine buildings already constructed out of the stone. However, the value of opinions based solely upon quarry observations or the inspection of buildings depend largely upon the

judgment and experience of the observer. They lack a definiteness and certainty which can only be supplied by the laboratory tests. No one of these should be considered sufficient in itself, but each should be used in conjunction with the other two.

QUARRY OBSERVATIONS

Several important conclusions may result from quarry observations which cannot be reached through an examination of buildings or selected samples in the laboratory. Chief among these may be mentioned: (1) the probable injury to the stone from quarrying, handling, and dressing; (2) the capacity of the quarry to furnish as needed the required quantity of stone of the desired quality; (3) the uniformity in color and mineralogical composition, and the apparent uniformity in strength, hardness, elasticity, and porosity.

Stone is often more or less injured through improper methods of quarrying and dressing or careless handling, as explained in the previous paper.[1] One can become familiar with the methods employed in quarrying the stone only by visiting the quarry where the work is being carried on.

The knowledge that a quarry has the capacity to furnish as needed the required quantity of stone of the desired quality is an important matter. A quarry is sometimes poorly equipped with machinery; men may be scarce; orders for stone may be plentiful; and as a consequence inferior stone is placed upon the market for the better grade. The situation of the quarry in these respects can be best determined by an examination of the quarry and its equipment.

The uniformity in the color of the stone can be quickly determined by an examination of the quarry. If the stone differs in color at different horizons, or in different parts of the quarry, precautions can be taken in the specifications to insure the receipt of stone of a uniform color by designating that it be taken from a definite part of the quarry.

[1] JOUR. GEOL., Vol. III, No. 2, pp. 181–184.

Stone from different parts of the same quarry may differ widely in mineralogical composition, strength, hardness, elasticity, and porosity. Differences in these respects, when of importance, may be detected through quarry observations. However, in order to ascertain these differences, one needs to be thoroughly familiar with the conditions controlling these properties. Differences in mineralogical composition may be recognized by one who is familiar with the common rock-forming minerals.

Differences in the strength of stone result from differences in mineralogical composition, and in size, shape, and manner of contact of the individual grains, all of which can be made out by an experienced observer.

Not only can an experienced person detect differences in the qualities of stone from various parts of the same quarry, but he can also make comparisons with stone from other known localities.

At the quarry the unweathered stone can be compared with that of the natural outcrop which has been exposed to the atmosphere for many years. Comparisons based upon such observations furnish very fair estimates of the permanence of color and the degree of hardness, strength, and durability of the stone. Such estimates, however, must necessarily be very general, because of the uncertain length of time that the weathered stone has been exposed to the atmosphere. It may have been uncovered for centuries, or perhaps for only a few years.

In the outcrop the stone may be found bleached, stained with brown, or discolored with white efflorescent patches. Bleaching ordinarily proceeds very slowly and extends to no great depth, and is therefore of little importance. Brown staining usually indicates the presence of iron, and the white efflorescent patches give evidence of magnesium or calcium salts.

In glaciated regions the hardness of a rock is frequently estimated by the depth and extent to which the surface has been grooved or striated. However, this is a very uncertain evidence of hardness, being controlled largely by the condition of the

glaciers as they passed over the region in question, and the length of time that the surfaces have been exposed to the atmosphere since glaciation.

The durability of a stone is occasionally estimated from the depth to which disintegration has extended. The extent of disintegration, however, has the uncertain time element in it, which may vitiate the conclusions.

Observations on stone in the natural exposure, where disintegration has not gone too far, reveal inequalities in hardness caused by concretions, nodules, pebbles, clay seams or pockets, and fossils. Weathering also emphasizes sedimentary and jointing planes, which are obscure in the freshly quarried rock. It is often contended by quarrymen that joints die out with depth, but this cannot be laid down as a general rule. Some joints are probably superficial, but others certainly penetrate to very considerable depths. The farther the joints extend laterally, the greater is the probability that they will continue to a considerable depth.

A luxuriant growth of lichens on a natural exposure of rock is frequently taken as evidence of durability. Unfortunately this criterion of durability, when taken alone, has little significance. An abundant growth of lichens has often been observed on the surface of sandstone which was inherently soft. Such occurrences simply indicated that a crust had been formed on the exposed surface of the stone.

If one is desirous of obtaining a considerable quantity of stone perfectly uniform in color and texture, it is important that he should visit the quarry to assure himself that the amount of stone of the desired quality is obtainable. It is possible for a quarry to be exhausted of its good stone, and for this reason, an inspection is often a valuable precaution. On the other hand, the stone from a certain quarry, which has a large percentage of number one stone, may have been condemned by the public, because quarrymen and contractor have permitted the use of a few inferior blocks, "for the sake of economy." In order to know when the best stone that a quarry produces is being

received, one should be personally acquainted with the possibilities of the quarry.

OBSERVATIONS ON BUILDINGS

The inspection of constructions of long standing is generally recognized as an important means of estimating the strength and durability of stone. The value of such observations, however, is often overestimated and it frequently happens that strong and durable stone is condemned on account of careless methods of handling and laying.

An estimate of the strength and durability of a stone from its condition in a building should only be made after one has considered, (1) the age of the building; (2) its size; (3) the climatic or atmospheric conditions; (4) its position; (5) the grade of stone used, and (6) the manner in which the stone was quarried, handled, dressed, and laid.

The age of a building is especially important, it being worse than folly to pass judgment on the stone in a building, unless this is known. A stone may not exhibit any material deterioration during the first twenty-five years in a wall, although the next ten years may show marked decay. As a rule the actual disintegration of the stone in buildings in the United States is comparatively little. Many that are fifty or more years old do not exhibit the first signs of decay. The actual disintegration is frequently so little that the observer must content himself with searching for the beginnings of decay.

The height of a building usually increases the weight of the superstructure and hastens the rate of decay. The atmospheric or climatic conditions, temperate, torrid, frigid, humid, or arid, will affect the permanence of a rock. A stone which would remain unchanged for centuries in an arid region might crumble and decay in a few years in a moist, temperate climate.

The position of a building, in the business or residence part of a city, protected or exposed to the storms and prevailing winds, will affect more or less the life of the stone.

The grade of stone that has been used in the construction of the building under inspection should be known. Nearly every quarry contains more than one grade of stone. However, it is not an uncommon occurrence for the stone from an entire district to be condemned because second or third grade stone has not proved as satisfactory as number one stone from another district. The poorer grades of stone are sometimes used in the fronts of buildings or even carved for the finer parts of the architectural work.

After the stone once becomes a part of a building people do not stop to distinguish different grades, but charge all weaknesses or imperfections against the quarry as a whole. Sometimes an entire area including several quarries suffers in consequence.

It is also important to know the manner in which the stone is quarried, handled, dressed, and laid. Much stone is still being laid on edge, especially in veneer work. Where the bedding planes are prominent and the stone is only of moderate strength, this practice is dangerous. An observer should ascertain if possible whether the flaking and scaling is due to improper methods of laying or to inherent weaknesses in the stone.

Stone used for ornamental and monumental purposes will show deterioration in proportion to its age, position, etc., the same as stone in the walls of buildings. For these reasons, the same care should be exercised in passing judgment on its durability.

The oldest monuments are built out of marble, it being only within a comparatively few years that granite has come into very general use. Nevertheless, some of the important granite monuments, in spite of the comparatively recent data of their erection, are gradually losing their polish and even now have finely pitted surfaces. Monuments that are exposed for years to dust laden winds frequently have their polished surfaces dulled and the lettering obscured. The sides exposed to the direct rays of the sun often deteriorate most rapidly owing to the diurnal expansion and contraction caused by heating and cooling.

The degree of polish which a stone will take and the contrast of the hammered and polished surfaces can be best estimated from the finished work. One should be mindful, however, at all times, in making comparisons, not to allow the elaborateness or excellence of the workmanship to influence the judgment. Dealers sometimes oil the polished surfaces of the monuments, which gives a brilliancy and luster not inherent in the stone itself. For this reason a monument should only be examined after it has been erected for six months or a year.

In the case of stone used for highways and sidewalks much can be learned of its strength and durability by inspecting previously constructed walks and roadways. In these cases, however, a just comparison can only be made when the manner in which the highway or walk has been constructed, the amount of traffic to which it has been subject, the character of the subsoil, the climate conditions, and the data of construction are known. The rapidity and manner in which a stone pavement wears are the important factors to be determined. An examination of pavements built out of the stone will indicate whether it wears unevenly, is slippery, or is easily abraded.

LABORATORY TESTS

One who is fully acquainted with the mineralogical and chemical composition, the physical characteristics of a stone, and the climatic and other conditions to which it will be subject when in use, can predict with a remarkable degree of accuracy, without inspecting the quarry or examining buildings of long standing, the results of exposure to the atmosphere. It is not always possible to have a laboratory examination made, and frequently it is unsought for by quarrymen, who often prefer to rely upon their own statements to sell their stone.

The important laboratory tests are included under three general classes, viz., (1) chemical; (2) microscopical; and (3) physical.

CHEMICAL

The chemical analysis is the only exact method of determining the composition of a rock in terms of the elements that compose it. It is also the best method of determining the relative proportions of the mineral constituents. The presence of deleterious constituents, such as ferrous iron, bitumen, etc., and the proportion that they bear to the total mass of the rock may also be determined in this way.

MICROSCOPICAL

Much may be learned of the mineralogical composition and physical characteristics of most rocks by a careful examination of the hand specimen, especially with the aid of a magnifying glass. Many rocks, however, are so fine grained that the mineralogical composition and texture can only be accurately determined by an examination of thin sections under a compound microscope.

It is thought that the microscopical examination is of much greater practical importance and less expensive than the chemical analysis. By use of the microscope and thin sections both the mineralogical composition and texture of a rock can be determined with a high degree of accuracy. The relative abundance of the different minerals and even the chemical composition can be approximately estimated. Minerals that are easily decomposed and liable to cause discoloration can be identified, and the presence of cracks, strains, and gas bubbles can be detected. A single caution should be observed in this connection. Cracks and strains are thought to be frequently due to stresses resulting from cutting and grinding the thin section, on account of which care should be exercised in drawing conclusions therefrom. The size and abundance of the pore spaces can be estimated from the texture, closeness, and manner of contact of the grains. All the characteristics of a rock which contribute to its strength, hardness, elasticity, capacity to resist alternating and extreme temperatures, and immunity from the

effects of carbonated or acidulated waters, can be determined by the microscopic examination of thin sections.

It is thought that the use of the microscope, with an intelligent interpretation of the facts revealed thereby, might eventually render unnecessary the performance of the physical tests and the determination of the chemical composition. However, at the present time, this method is only available to the scientist who can interpret the facts thus observed. The accuracy of his conclusions will depend upon his judgment and experience as a petrographer. With the public it may never supplant the physical tests, because it lacks the quantitative element.

PHYSICAL TESTS

The purpose of the physical tests is to determine by artificial methods the strength of a stone and its capacity to resist the destructive agents encountered in actual use. As stated on a previous page, the signs of decay in buildings, on account of the improper methods of quarrying, handling, dressing, and laying are not always evidence of inherent weakness in the stone. For this reason the physical tests, performed in the laboratory, often provide a more reliable basis on which to estimate strength and durability.

It is a comparatively simple matter to determine the strength and elasticity of a stone, both of which can be measured directly by machinery. It is a more difficult problem, however, to express quantitatively the durability, on account of the impossibility of measuring in a few weeks or months in the laboratory any deterioration that might take place under ordinary climatic conditions. Further than this the conditions in nature change from day to day, both in intensity and kind, and as a rule, there are several instead of one agent of destruction operating at the same time. In order to measure the effect of these agents in the laboratory it is necessary to consider them separately, and on such a grossly exaggerated scale that there will be accomplished in a brief period, what in nature would require many years.

Estimates of the strength and durability of a stone from physical tests are usually based upon the following determinations:

1. *Strength*,
   a. Compressive,
   b. Transverse.
2. *Elasticity, modulus of*.
3. *Hardness—coefficient of wear*.
4. *Specific gravity*.
5. *Porosity*.
6. *Weight per cubic foot*.
7. *Effect of Temperature changes*,
   a. Freezing and thawing of included water,
   b. Effect of extreme heat.
8. *Effect of gases*,
   a. Carbonic acid,
   b. Sulphurous acid.

Attempts have been made to classify these tests under "strength tests" and "durability tests," but the classifications thus made are not logical because some of the tests have a double significance.

STRENGTH

A knowledge of the strength of a stone implies a familiarity with its capacity to withstand both compressive and tensile stresses. For this reason both the crushing strength and modulus of rupture should be determined.

Crushing strength.—Up to within a few years the compressive strength test, by means of which the crushing or ultimate strength is determined, has been used for estimating both the durability and strength of a stone. However, a stone with a low crushing strength may be more durable than one in which the crushing strength is high. For this reason the crushing strength, alone, is insufficient for estimating the durability of a stone. In the absence of other tests the importance of the crushing strength has been frequently overestimated.

At the present time, however, it is argued by some that it is folly to determine the crushing strength, except in cases where the strength of the stone is very doubtful. Nevertheless, I do not believe that it is wise to encourage the abandonment of the crushing strength test.

Architects using stone with which they are not familiar, are glad to avail themselves of all crushing strength data. In fact, the only intelligible method of expressing the strength of a stone to one not thoroughly familiar with the interpretation of the mineralogical composition and texture, is in pounds per square inch.

Other than this the crushing strength determinations have an important scientific bearing upon problems in dynamic geology, and for this reason if no other the test should be continued.

It is not uncommon for a stone to be so situated in a building that it must sustain a heavy load. In very large buildings single columns and blocks are often required to carry huge masses of superstructure. Bridge trusses are often supported on blocks of stone which sustain the combined weight of the superstructure. Before using a stone for any of these purposes it is well to know with a fair degree of accuracy its crushing strength.

The pressure exerted on the stone in the lower courses of a building of ordinary dimensions is not very great. It has been computed that the stone at the base of Washington monument sustains a maximum pressure of 22.658 tons per square foot, or 314.6 pounds per square inch. Most architects require a stone to withstand twenty times the pressure to which it will be subjected in the wall. This factor of safety, however, would only require a crushing strength of 6292 pounds per square inch for stone at the base of the Washington monument. The pressure at the base of the tallest buildings yet constructed in this country can scarcely exceed one half that at the base of this monument, or 157.3 pounds per square inch. With a factor of safety of twenty the stone used in such positions must have a crushing strength of 3146 pounds per square inch. There are very few

building stones in the country that do not have a higher crushing strength. It may happen, however, that owing to an unequal distribution of the load certain stones in the wall or columns, will be called upon to sustain twenty, or even fifty times the natural load, in which case the crushing strength should be much greater. All things considered, however, a crushing strength of 5000 pounds per square inch is considered sufficient for all ordinary building constructions.

The crushing strength of a stone can be obtained quickly and accurately in any laboratory which is provided with appliances for cutting and dressing stone cubes and a testing machine, for determining the compressive strength. The cubes to be tested should measure uniformly $2 \times 2 \times 2$ inches, this being generally conceded to be the standard size. Smaller or larger cubes may be used, but some authors, following the early experiments of General Gilmore, still maintain that the crushing strength per unit of area varies with the size of the cube tested. Believing this, General Gilmore constructed an empirical formula for the purpose of reducing all tests to pounds per square inch on two-inch cubes. However, it has been shown to the satisfaction of most persons, that this formula is neither theoretically nor practically true. It is now believed quite generally that the crushing strength per square inch is the same whether the cubes tested be large or small; cubical or prismatic in shape. Until this question is settled to the satisfaction of all it is best that all tests be made upon two-inch cubes.

The cubes should be very carefully sawed from stone which has not been injured by rough handling or hammer dressing. The faces should be rubbed smooth, and the opposite sides should be made parallel. Before the cubes are placed in the testing machine they should be thoroughly dried and the average area of the bearing faces determined. Thin strips of blotting paper, wood, or lead, are often placed between the steel plates of the machine and the bearing faces of the stone cubes, to assist in distributing the load. It is claimed by some, however, that this has a tendency to lower the crushing strength. The

author believes, that for the sake of uniformity, at least, it would be best to apply the bearing faces directly to the steel plates of the machine, a spherical compression block being used in making the test. Record should be kept of the direction in which the pressure is applied with respect to bedding.

The load at which the cubes are first cracked, the ultimate strength, the perfection of the resulting pyramids, and the explosive manner in which the cubes break should be carefully noted. The crushing strength per square inch is computed by dividing the ultimate strength by the average area of the bearing surfaces in square inches.

Transverse strength.—The transverse strength is measured in terms of the modulus of rupture. This is the force required to break a bar of any material one inch square, when resting on supports one inch apart, the load being applied in the middle. The determination of the modulus of rupture is of far greater importance in masonry construction than would be supposed from the very meager data available. The broken lintels, caps, and sills which are so conspicuous in many of the larger buildings in this country, testify to the need of a more general appreciation of the value of this test. Many building stones that are perfectly suited to withstand the compressive stresses in the body of the wall, have such a low modulus of rupture as to be unfit for use in a position where a high transverse strength is required.

The necessary thickness of a lintel, cap, or sill depends mainly upon the transverse strength of the stone. In order to avoid possible danger from weak stone or unequal stresses, the doors and windows of the heavier buildings are often arched.

For the purpose of obtaining the modulus of rupture, pieces should be prepared by sawing, and should have a cross section of one square inch and a length of from six to eight inches. The sides should be smooth and the opposite faces parallel. The pieces thus prepared should be placed in a testing machine, in which both ends are supported and the pressure applied in the middle. The weight required to break the sample and the

position of the rupture should be carefully recorded. The modulus of rupture is then computed from the following formula:

$$W = \frac{2bd}{3l} R, \text{ from which}$$

$$R = \frac{3l}{2bd} W.$$

W = concentrated load at center in pounds.
b = breadth in inches.
d = depth in inches.
l = length.
R = modulus of rupture in lbs. per sq. in.

Modulus of elasticity.—The modulus of elasticity is synonymous with coefficient of elasticity, and is sometimes defined as the weight that would be required to stretch a rod one square inch in section to double its length. The result is generally expressed in pounds per square inch. It is "valuable in determining the effect of combining masonry and metal, of joining different kinds of masonry, or of joining new masonry to old; in calculating the effect of loading a masonry arch; in proportioning abutments and piers of railroad bridges subject to shock," etc. Baker.)

One method of measuring the modulus of elasticity is by recording the amount of compression which a two-inch cube of stone undergoes for each increment of 500 to 1000 pounds up to the limit of elasticity. From the data thus obtained the modulus of elasticity is computed by use of an empirical formula.

The value of such determinations from a commercial standpoint are somewhat doubtful, owing to the fact they are seldom referred to by architects. The sparcity of the determinations in this country is undoubtedly one reason for their uselessness.

Hardness.—The hardness of a stone may be determined quantitatively by the use of an abrading machine, and the results expressed as the coefficient of wear. The abrasion test is used mainly for determining the wearing qualities of crushed rock for

macadam but it is thought that such tests will prove valuable and important for determining the suitability of stone for steps, sidewalks, and flooring.

The abrading machine that is considered best suited for determining the coefficient of wear is that used by the Wisconsin Geological Survey, and patterned after the machine used by the Massachusetts Highway Commission.[1]

Specific gravity.—The determinations of the specific gravity of building stones that have come under my observation have been based upon two very different conceptions. According to one of these conceptions the specific gravity depends entirely upon the mineralogical composition, and is independent of the porosity of the stone. According to the other conception the pores are considered a part of the stone and the specific gravity is computed for the exterior volume. These two methods give different results for the same stone, and have been designated by Regis Chauvenet as "Specific Gravity Proper" and "Apparent Specific Gravity." Where the porosity of a stone is less than 1 per cent. the two specific gravities are almost the same. But where the porosity is 10 or 25 per cent., they are very different.

In most discussions of building stone tests the principle laid down by Professor J. C. Smock[2] that, the specific gravity of the *particles or mineral species* composing the rock mass, determines that of the stone has been followed.

The practical engineer, however, objects to this method, because he cannot compute the weight of the stone per cubic foot directly by multiplying by 62.5, the weight of an equal volume of water. Several contemporary writers on building stones, however, have unfortunately made the mistake of determining the "specific gravity proper" and then computing the weight per cubic foot by multiplying this directly by 62.5. For

[1] For description of this machine see the Report of the Massachusetts Highway Commission for 1899, pp. 59, 60.

[2] Bulletin of New York State Museum, Vol. II, No. 10, p. 374, PROFESSOR J. C. SMOCK.

example one author gives the following as the results of his experiments on three different stones.[1]

Number	Specific gravity	Weight in lbs. per cubic foot	Per cent. of water absorbed
C 2314	2.6236	163.50	18.07
C 2183	2.6166	163.07	3.62
C 2316	2.5380	158.17	8.71

It will be observed as a result of these experiments that the stone which absorbed 18.07 per cent. of water weighed more than the one that absorbed only 3.62 per cent., although the difference in specific gravity is only .007.

Another author says: "If we find that a stone has a specific gravity of 2.65 . . . . we get its weight by simply multiplying 62.5 by 2.65 which gives us 165.62 . . . ."[2] In this statement reference is made to the "specific gravity proper" and not the "apparent specific gravity." Results obtained in this way would obviously be incorrect. Similar inaccuracies in the determination of the specific gravity and weight per cubic foot, occur in other published reports, but those above quoted suffice as illustrations.

I believe that the specific gravity should be determined on the principle laid down by Professor J. C. Smock[3] and that the "apparent" specific gravity should only be used in computing the weight of the stone per cubic foot. There is no inconsistency in this, in so much as the commercial weight considers only the external volume and does not consider the stone as a geometric solid. At least there should be a recognized uniform method of computing the specific gravity of stone.

The specific gravity proper of a rock can only be obtained by weighing the samples in air, at a definite temperature, after all interstitial water has been expelled; then weighing them,

[1] Bulletin of New York State Museum, Vol. II, No. 10, Table, p. 358, by FRANCIS A. WILBER.

[2] The Building and Decorative Stones of Maryland. Maryland Geological Survey, Vol. II, p. 119, GEO. P. MERRILL.

[3] *Ibid.*

completely saturated with water, in water; and finally dividing the weight in air by the difference. These ideal conditions of absolute freedom from interstitial water in the one case, and complete saturation in the other, are difficult to obtain. Nevertheless, if accurate methods are employed and care is exercised in manipulation it is thought that a high degree of accuracy can be attained.

As previously stated, it is advisable to perform all tests on two-inch cubes. In obtaining the specific gravity, the samples should be cleaned by carefully washing, and dried for twenty-four hours in a hot air bath at a temperature of 110° C. The samples should then be weighed and the weights recorded in grams to the second decimal place. The samples should then be transferred to a large bottle or other glass receptacle, corked tightly, and sealed. This bottle should then be transferred to a water bath having a temperature of 100° C. Three glass tubes, one leading to an air pump, another to a manometer, and a third to a basin of boiling water are passed into the bottle through holes in the cork. By means of the air pump, the air in the bottle should be exhausted until the pressure, as indicated by the manometer attachment, is lowered to at least one twelfth of an atmosphere. The pressure should be maintained at this point while distilled water at a temperature of 100° C is drawn into the bottle through the third tube. This tube which conveys the water should be partly rubber and should extend to the bottom of the bottle. A stop cock is used to regulate it. By starting the air pump and operating the stop cock at the same time it is possible to keep the pressure nearly constant and at the same time draw any desired amount of water into the bottle. By this process, the air in the pores is gradually replaced by the water which fills the vessel from below. After the cubes are completely covered with water, they should be allowed to remain in the bottle twenty-four hours maintaining a pressure of one twelfth of an atmosphere.

The saturated samples should then be quickly transferred to a basin of distilled water and removed to the weighing room.

After removing the samples from the basin, the water adhering to the surface should be deftly removed by the use of bibulous paper, the samples transferred to the scale pan, and quickly weighed. Through the transference of the samples from the basin to the scale pan there are two sources of error, one is through the use of bibulous paper, and the other through evaporation. No plan has yet been devised to avoid these sources of error, wherefore the skill and judgment of the operator must be depended upon.

After these weights are recorded the samples should be suspended by a silk thread in distilled water and again weighed. After this weight is recorded the samples should be transferred to a hot air bath and dried at a temperature of 110° C. until the interstitial water has been entirely expelled. The samples are again weighed and the results recorded. From the weights thus obtained the specific gravity is determined by dividing the average of the two dry weights by the difference between the average dry weight and the weight of the cube suspended in water.

The apparent specific gravity can be readily obtained by subtracting the weight of the sample suspended in water from the weight of the sample saturated with water and dividing the average dry weight by this difference.

Porosity and ratio of absorption.—These terms have been used interchangeably as applying to the percentage of the weight of the absorbed water to the average weight of the dry sample. This ratio, however, is not the percentage of actual pore space, but simply the relation between the weight of the rock and the weight of the water absorbed. The term porosity should only be applied to the percentage of actual pore space in the rock while the ratio of absorption should be restricted to the percentage of the weight of the absorbed water to the average weight of the dry sample. The former gives the volume relation and the latter the weight relation. To my knowledge no American writer has computed the actual pore space or porosity of building stones. However, I believe that this determination is more important than the ratio of absorption.

The method of obtaining the porosity which is ordinarily employed is as follows: The sample to be tested is heated at a temperature of 100° C. to drive off the moisture. After cooling, the sample is weighed, and then slowly immersed in distilled water. After bubbles cease to be given off, the sample is removed from the water and the surface quickly dried with bibulous paper, after which the specimen is again weighed. The difference in weight gives the increase due to the absorption of water. This difference divided by the weight of the dry stone is taken as the ratio of absorption or porosity.

Several errors are apparent in this method. The interstitial water is not easily expelled at a temperature of 100° C. To expel the moisture in a moderate length of time, the stone should be dried at a temperature of 110° C. Further, the samples cannot be completely saturated "by immersing in distilled water until bubbles cease to be given off." Finally the method of computation gives the ratio of absorption and not the percentage of actual pore space or porosity.

The porosity of a stone should be obtained in the following manner, using the determinations made in performing the specific gravity tests. The average weight of the dry sample should be subtracted from the weight of the saturated sample, to obtain the weight of the water absorbed. This, multiplied by the specific gravity of the stone, will give the weight of a quantity of stone equal in volume to the pore space and of the same specific gravity as the stone tested. This weight divided by the weight of the dry stone will be the porosity or actual percentage of pore space.

The ratio of absorption can be obtained by dividing the weight of the absorbed water by the weight of the dry stone.

In another part of this paper I have shown that neither the porosity or ratio of absorption, alone, indicates the value of a stone for building purposes. It was pointed out that the size of the pores is by far the more important consideration. This can be estimated roughly, when the size and shape of the grains and percentage of pore space are known. If only the ratio of

absorption is available the calculations of the size of the pores are liable to be less accurate.

For scientific purposes, other than determining the quality of a stone for building, the porosity, and not the ratio of absorption is the factor sought after. The porosity test will result in a higher percentage than the ratio of absorption, and may therefore meet with disfavor among quarrymen. However, when it becomes known that the value of a stone cannot be estimated from its porosity except when the size of the pore spaces is known, objections will cease. In all cases it is thought that the porosity should be determined in preference to the ratio of absorption.

Weight per cubic foot of stone.—The weight of stone when it is first quarried, depends upon its specific gravity, the amount of pore space, and the water content. For a given stone, the only fluctuating element is the water content. In the more porous rocks this will vary at different seasons of the year and will depend upon the thoroughness with which the rock has been seasoned. Any determination of the weight per cubic foot of a stone which includes an indefinite quantity of interstitial water is unscientific and unsatisfactory. Determinations thus made depend upon a number of conditions, changes in any one of which will give a different result. The only constant weight is that of the dry stone.

The commercial weight of a stone may be obtained in two ways. First, by weighing directly a known volume of the stone which has been thoroughly dried at a temperature of 110° C.; second, by computation from the data obtained in determining the porosity. By the second method, the weight of a cubic foot of stone can be obtained by multiplying the weight of a cubic foot of water by the specific gravity proper of the stone and subtracting therefrom the weight of a mass of stone, equal in volume to the pore space of the given rock and of the same specific gravity.

A simpler method would be to compute the apparent specific gravity as directed above and multiply by 62.5, which should give the same result.

Effect of temperature changes.— The durability of a stone depends very largely upon its capacity to withstand temperature changes. Such changes may affect the mineral constituents of rock through expansion and contraction, or they may cause the interstitial water to freeze and thaw, on account of which the strength of the stone may be materially lessened.

Very few tests have thus far been made to determine the effect on building stone, of the alternate freezing and thawing of interstitial water. The importance of such experiments has never been questioned, but the difficulty of manipulation and the many conditions which need consideration before conclusions can be drawn from the quantitative results, have had the effect of almost excluding these tests from the experiments on building stone.

The effect of alternate freezing and thawing may manifest itself in three ways: first, cracks may form; second, small particles or grains may be thrown off from the surface occasioning a loss in weight; third, the strength of the sample may be lessened. The first result is very seldom observed in testing samples in the laboratory, owing to the careful selection of the pieces tested. The other two, however, usually occur and can be measured quantitatively.

Two methods, known as the natural and the artificial, have been employed to determine the effect of alternate freezing and thawing of the interstitial water. The natural method is to soak the samples with water and alternately freeze and thaw them, a few or many times, at the convenience of the operator. The artificial method is to saturate the stone in a boiling solution of soluble salt, such as sodium sulphate, and then allow it to dry. As the water evaporates the salt crystallizes and expands, producing stresses similar to those which result from freezing water. It appears to me that the only instance in which it is excusable to use this method is when there is no opportunity to freeze the samples under conditions which more nearly accord with those which occur in nature.

For the purpose of testing stone according to the natural method, the operator should use two-inch cubes as in the

previous experiments. If the tests are made during the winter months when the temperature is below the freezing point, the samples can be saturated with water, cooled to nearly the freezing point, and then placed out of doors. If freezing temperatures do not prevail in the climate where the experiments are being performed, access may be had to a cold storage building where the necessary temperature may be obtained. Freezing mixtures may also be used to produce the desired temperature.

The samples to be tested should first be thoroughly cleaned and dried in a hot air bath at a temperature of 110° C. and weighed. After the samples are thoroughly saturated with distilled water, after the manner outlined in the specific gravity test, they should be cooled almost to the freezing point, taken from the water and removed to the place of freezing and allowed to remain for twenty-four hours. The samples should be thawed, saturated, and frozen alternately each day for a period of thirty or forty days, after which they should be placed in a hot air bath and dried at a temperature of 110° C. They should then be removed to the weighing room and weighed. This final weight subtracted from the first gives the loss in weight. The samples should be examined to discover any cracks that may have formed as a result of the freezing.

Finally the frozen cubes should be crushed in a testing machine to determine their compressive strength. The results thus obtained should be compared with the strength tests made on unfrozen cubes of the same stone.

The loss in weight during a period of thirty-five days has been found to be due mainly to the removal from the surface of small particles which were previously loosened, in the process of cutting the sample. Many of the grains at the surface of sandstone samples which have been sawed or hammer-dressed are partly loosened. Such grains fall away from the mass of the stone very easily. The pressure which is supplied by the freezing water, which fills the cracks and pores near the surface, is abundantly able to accomplish this.

Naturally, sedimentary rocks, such as sandstone, have more loose grains at the surface than the igneous rocks or finely crystalline limestone. However, in any case, alternate freezing and thawing for a period of thirty-five days will scarcely result in anything further than the removal of the loose particles from the surface. If the process is continued for another thirty-five days it is probable that in the case of sandstone the loss during this period will be far less than that of the first period. Even though the loss should be as great, the results could not be justly compared, except between the same kinds of stone.

To my knowledge, the loss in crushing strength due to freezing has not received the least consideration by any previous writer on building stones. As inferred above, I believe that the tests heretofore made to determine the loss in weight are of comparative little value in estimating the effect of freezing and thawing on the durability of a stone. The determination of the loss in crushing strength is obviously more important. It is evident that if a stone is saturated with water and frozen while a portion of the pores are still filled with water and the process is repeated a score or more of times, the adhesion of the particles will be weakened. It is not reasonable to suppose that the strains produced can be measured by the immediate loss in weight. It is plausible to suppose that the deterioration can be better measured by the loss in strength.

Experiments performed in the preparation of the report on the "Building Stones of Wisconsin" confirm my impression regarding the value of the crushing strength test applied in this manner. I feel quite confident that this test is more important than the determination of the loss in weight, and should, I believe, eventually take precedence in the testing of building stones.

Extreme heat.—Very few tests have been performed to ascertain the effect of heat or cold when applied directly to stone, yet it is known from observation that rapid and extreme changes in temperature weaken a rock and often cause disintegration. In large cities, the capacity to withstand extreme heat is one of

the essential qualities of a good building stone. In the conflagrations which have occurred in many cities, brick, stone, and wooden structures have suffered alike. Granite and brick walls have crumbled into shapeless masses, while iron beams and girders have been melted and twisted into all conceivable shapes.

A comparatively low temperature destroys some materials, while others are barely affected at a temperature above the melting point of copper. Most building materials, however, are destroyed when subjected to a very high heat.

It is known that rocks are poor conductors of heat, and for this reason the outer shell of a block may be very highly heated while the interior is comparatively cold. If a block is quickly cooled after heating, contraction of the outer shell takes place, and the differential stresses occasioned thereby rupture the rock.

The destruction caused by a conflagration is largely increased by streams of water which are thrown onto the burning buildings in an attempt to extinguish the flames. If the fire occurs in winter the effect is still further intensified by the freezing of the water.

Few experiments have thus far been performed to determine the temperature which the different kinds of stone will stand without injury. It has, however, been demonstrated that stone will withstand a much higher temperature when heated and cooled slowly than when heated and cooled rapidly.

The easiest method to test the capacity of a stone to withstand heat is to place two-inch cubes in a muffle furnace and gradually heat them from a low to a high temperature. By using a standard pyrometer the temperature can be gauged and the visible effect of any increase in heat can be noted. Samples should be tested not only to ascertain the effect of gradual heating and cooling, but they should also be removed from the furnace and suddenly cooled by plunging into cold water.

Limestone and dolomite are injured mainly through calcination, although when suddenly cooled they flake at the corners. Coarse grained granite is often shattered throughout its mass. Medium grained granite flakes at the corners, while the compact,

fine grained varieties are often traversed by sharply defined cracks. In contrast with the limestone and granite, sandstone has all outward appearance of being very little injured by extreme heat. However, it is often so soft after being subjected to extreme heat that one can crumble it between the fingers. The extent to which a coarse grained sandstone has been injured by extreme heat cannot be determined until the strength of the stone has been actually tested. All the stone that has been heated to a high temperature emits the characteristic ring, and scratch of brick. The cause for this may be found in the loss of the water of composition by the minerals of the rock.

Experiments seem to indicate that there are few, if any, stones, whether they be granite, limestone, or sandstone, that will effectually withstand a temperature of 1500° F. A rock with a uniform texture and a simple mineralogical composition apparently suffers the least injury when subjected to high temperatures.

It would be interesting to know the loss of strength occasioned by each increase in temperature of 100 or 200° for the different kinds of building stones. This can only be determined by a careful series of experiments, and it is hoped that in the future some one will undertake this task.

The effect of sulphurous acid gas.—Limestone, dolomite, and marble are the only kinds of stone which are to any extent injured by sulphurous acid gas. To determine the effect of this gas upon dolomite or limestone, two-inch cubes are dried at a temperature of 110° C. and carefully weighed. They are then placed in a wide mouthed bottle, in the bottom of which is placed a beaker of water to keep the air moist. The bottle is sealed and each day sufficient sulphur dioxide is transferred into the bottle to keep the atmosphere saturated. The samples should be allowed to remain forty-four days in this atmosphere saturated with sulphur dioxide. After being removed from the bottle the samples should be washed and thoroughly dried at a temperature of 110° C. They should finally be weighed and the loss in weight determined. The percentage of loss in weight is taken as the result. The loss in this case is due mainly to the

magnesium and calcium salts which collect at the surface and are dissolved by the water when the samples are washed.

Effect of carbonic acid gas.—The effect of carbonic acid gas on limestone is determined in the same manner as that of sulphurous acid gas. The samples are dried at a temperature of 110° C. and weighed. They are then placed in a wide mouthed bottle which is filled with carbonic acid gas. A beaker of water is placed in the bottle to keep the atmosphere moist. After being treated for forty-four days the samples are removed, washed, and weighed. The percentage of loss in weight is taken as the result.

Sulphur dioxide and carbon dioxide probably do not at any time exist alone in the atmosphere. The effect of these gases acting together or in conjunction with the many less abundant gases of the atmosphere may produce very different results than when acting separately.

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EDITORIAL

AN unsigned article in *Science* (June 22) entitled "Sigma Xi at the American Association for the Advancement of Science," calls attention approvingly to a movement to associate meetings of this Greek-letter society with those of the Association. The rapid rise of the Sigma Xi in American universities is cited, and it is affirmed that "as an honor society it promises to take a leading part in our universities in which science holds a prominent place." It is urged that "it has become a representative honor society for the ablest students of science in the institutions where it is established." Respecting its intent, the following authoritative quotation is made: "In establishing a new chapter . . . . in each case we should make sure that we entrust the power of distributing the honor of membership only to such persons and institutions as are capable of giving the education and training necessary to the carrying on of scientific investigation."

It is scarcely necessary to make these quotations to show that the fundamental feature of the society is the promotion of a class distinction based on academic preparation. However laudable this may be, in itself considered, it would seem to be inharmonious with the fundamental purpose of the Association, which is the development and dissemination of science among all people without regard to race, age, sex, or previous condition of intellectual servitude. From professional relations the writer should not be inappreciative of the value of university training and of academic achievement. Nevertheless, it seems to him that the purposes of the Association are unqualifiedly democratic and that the spirit of science is equally so, and that therefore the only distinctions which the Association should foster or sanction, if it fosters or sanctions distinctions at all, are those which are based solely upon scientific productiveness. And this productiveness should be honored quite irrespective of its connection

with the fortunate conditions of academic appointments and opportunities, or with the adverse or even hostile conditions under which much good science has been developed. The movement therefore to connect the meetings of the Sigma Xi with those of the Association seems incongruous.

As set forth in another article in the same number of *Science*, some fifteen special scientific societies have already become correlated with the Association and have much increased the complexity of the proceedings. This movement seems to be an inevitable consequence of the differentiation of scientific work, and is scarcely less than necessary to the continued success of the Association, but it has already brought some inevitable conflict of interests and not a little congestion of programs and appointments. Between these and the increased number of social functions, it has already come to pass that there is little time left for that personal conference and that informal sociability whose basis is "shop talk," which formed so large a factor in the attractiveness of the earlier meetings of the Association. If now in addition to these laudable complications, the attention of a considerable number of the members of the Association is to be diverted in the interest of an academic honor society and a precedent established for the meeting of other societies whose basis is not strictly congenial to that of the Association, it is not clear where the limit of congestion will be found.

Between the lines of the article referred to, the imagination is tempted to read a hint of a desire for that rank and dominance in the Association which the members of Sigma Xi attained in university circles, and it is not unnatural to anticipate that the fraternity might unconsciously play a part in Association politics not unlike that for which Greek-letter societies are famous throughout the university world. To those who pride themselves upon rank and band themselves together because of rank it is not unnatural that official expressions of rank should be sought through the unconscious influence of fraternization.

It is not altogether foreign to the subject of this discussion to note the increasing encroachments of formal social functions

upon the meetings of the Association and not less perhaps upon the meetings of the Geological Society of America. Without doubt a certain measure of formal contact with general society is helpful to the ends sought by the Association. At the same time it must be recognized that formal social functions are largely the province of the leisure class and that from the very nature of the case they must remain so, for leisure and the means of leisure are prerequisites to their effective cultivation. Equally from the nature of the case, the devotees of science do not usually belong to the leisure class because real success in science involves strenuous endeavor and an almost unlimited devotion of time. The diversion of time to social functions during the meetings of the Association should, therefore, be zealously watched and restrained within limits which are compatible with the efficient conduct of the primary purposes of the Association. Particularly is this true of the Geological Society which has no organic relation to general society. The movement in the direction of social formality has already crowded hard upon the point where the first requisite preparation for a meeting of the Association or of the Geological Society is the packing of a dress suit, and the second is the preparation of an after-dinner speech, preparations that are none too congenial to the great mass of hard workers in science.

T. C. C.

Reviews

The Illinois Glacial Lobe. By Frank Leverett, Monograph XXXVIII, U. S. Geological Survey, pp. 817. Plates XXIV, 9 figures. Washington, 1899.

This is one of a series of monographs in course of preparation by the Glacial Division of the United States Geological Survey, whose purpose is to set forth the salient features of the glacial formations preparatory to more detailed mapping by quadrangles, which the survey is undertaking, and by counties and other appropriate divisions, which many of the states are prosecuting. In a sense it may be said to be the first monograph of the systematic series. Two other monographs have been published, namely, that on Lake Agassiz, by Mr. Warren Upham, and that on the Glacial Gravels of Maine, by Professor George H. Stone, but these are special treatises on phenomena of exceptional interest and only indirectly form a part of the systematic series intended to cover the glacial area. The plan of the Survey departs somewhat widely from that prevalent in Europe where glacial work proceeds largely by minute studies of small areas without previous determination of the great features and broader classifications which can only be worked out by connected studies over large areas. The method of the United States Geological Survey has been to determine first these grand features and leading classifications and then descend in natural order to local details and more refined studies. Local mapping proceeds at great disadvantage without such preliminary determinations, for such is the nature of the glacial formations that these larger expressions of the phenomena of the period are very imperfectly expressed within any restricted area, and are quite beyond satisfactory interpretation unless the studies are extended beyond them.

The general reconnaissance work of the survey was essentially completed some years ago by the geologist in charge and the work of preparation of the monographs, as the second step of the plan, is now well under way. Besides the monograph under consideration, the manuscript of an additional one has been submitted and work upon a third is in progress.

The products of the Illinois glacial lobe constitute a natural monographic theme, for the differentiation of the border tract of the ice by the topographic influences of the trough of Lake Michigan gave the lobe a quite distinct individuality. In the monograph, however, for convenience the field is rather arbitrarily limited on the north where the products of the Illinois lobe become complicated on the east side with those of the Huron-Erie and the Saginaw lobes and on the west side with those of the Green Bay lobe. This limitation, however, does not seriously affect the unity of the theme. This lobe was given precedence because its field embraces the most southerly reach of the great ice mantle and because its products are unusually well deployed.

The author's abstract of the monograph which follows, sets forth its contents better than could be done by another.

Chapter I. Introduction.— The Illinois glacial lobe formed the southwestern part of the great ice field that extended from the high lands east and south of Hudson Bay southwestward over the basins of the Great Lakes and the north-central states as far as the Mississippi valley. It overlapped a previously glaciated region on the southwest, whose drift was derived from an ice field that moved southward from the central portion of the Dominion of Canada as far as the vicinity of the Missouri River. This southwestern part of the eastern ice field, being mainly within the limits of the State of Illinois, has received the name Illinois Glacial Lobe.

The results of earlier studies by Chamberlin, Salisbury, and others are noted, and the plan of investigation is set forth. A brief explanation of the method of numbering townships is presented.

Chapter II. Physical features.— The variations in altitude are set forth in a topographic map and also in tables, and the marked increase in altitude of certain parts of the region because of drift accumulations is considered. The conspicuous reliefs of the rock surface are briefly touched upon, and the preglacial valleys receive passing notice. Profiles and maps are extended across the bed of Lake Michigan as well as border districts, and the inequalities of the lake basin are briefly discussed.

Chapter III. Outline of time relations or glacial succession.— A sketch of the major and minor divisions of the drift sheets and of the intervals between them is accompanied by a brief explanation of the basis for the classification adopted.

Chapter IV. The Illinoian drift sheet and its relations.— The Illinoian is the most extensive drift sheet formed by the Illinois glacial lobe and receives its name because of its wide exposure in the State of Illinois. The evidence that the Illinoian drift sheet should be separated from the outlying and underlying drift is briefly set forth. The aspects of the Illinoian drift

sheet are then discussed, its topography as well as its structure being considered. In connection with this drift sheet a very adhesive clay known as "gumbo," which caps it, is described and the questions of its relation to this drift sheet and to the overlying loess are considered. A detailed description of the border of the Illinoian drift sheet is then given, which is followed by a description of the moraines and other drift aggregations back from the border.

Remarkable instances of the transportation of rock ledges are noted. The striæ pertaining to this invasion are discussed in some detail. The effect of this ice invasion and its drift deposits upon the outer-border drainage is touched upon, but the detailed discussion of the influence of the drift upon drainage is deferred to a later chapter. The chapter closes with a discussion of the deposits which underlie the Illinoian drift sheet.

Chapter V. The Yarmouth soil and weathered zone.— A well-defined soil and weathered zone which appear between the Kansan and Illinoian drift sheets in the overlap of the latter upon the former are described, and sections are represented which show clearly the relations to these drift sheets. The amount of erosion effected during the interglacial stage is also considered. The name Yarmouth is taken from a village in southeastern Iowa, where the interglacial features were first recognized by the writer.

Chapter VI. The Sangamon soil and weathered zone.— Another well-defined soil and accompanying weathered zone which appear between the Illinoian drift and the overlying loess are described. The name Sangamon is applied because these features are exceptionally well developed in the Sangamon River basin in Illinois and were there first noted by Worthen in the early reports of the Illinois Geological Survey.

Chapter VII. The Iowan drift sheet and associated deposits.— The name Iowan was applied by Chamberlin to a sheet which is well displayed in eastern Iowa and which had been brought to notice by McGee. The chapter opens with the discussion of a drift sheet of a similar age which was formed by the Illinois lobe, its extent, topographic expression, and structure being considered. The relation of this ice lobe to the Iowa ice lobe, and the relation of each to the great loess deposit of the Mississippi basin are then considered, after which the loess is discussed. The problem of the mode of deposition of the loess forms the closing topic.

Chapter VIII. The Peorian soil and weathered zone (Toronto formation). The name Toronto formation, suggested by Chamberlin, for interglacial deposits exposed in the vicinity of Toronto, Canada, may prove to be applicable to a soil and weathered zone which appear between the Iowan drift sheet or its associated loess and the Shelbyville or earliest Wisconsin drift sheet which overlies the Iowan. Exceptionally good exposures of a soil and weathered zone at this horizon in the vicinity of Peoria, Ill., make it seem

advisable to apply the name Peorian, while the relations of the Toronto formation remain uncertain, Other exposures as well as those near Peoria are discussed. A marked interglacial interval between the Iowan and Wisconsin stages of glaciation may also be inferred by a comparison of the outline of the ice sheet at the Iowan stage of glaciation with that of the outline at the culmination of the Wisconsin stage. It may also be inferred by a change in the attitude of the land, by which better drainage conditions were prevalent in the Wisconsin than in the Iowan stage.

Chapter IX. The early Wisconsin drift sheets. — The Wisconsin drift, named by Chamberlin from the state in which it was first recognized as a distinct drift, is characterized by large morainic ridges and comparatively smooth intervening till plains which have been thrown into two groups, known as the early Wisconsin and late Wisconsin. In the first group the moraines form a rudely concentric series, which are well displayed in the northeastern part of Illinois, but are largely overridden by the moraines and drift sheets of the later group in districts farther east. The outer border of the second, or late, Wisconsin group is so discordant with the moraines of the first group that there seems in this feature alone sufficient reason for separation.

The several morainic systems of the early Wisconsin group are taken up in succession from earlier to later, the distribution, relief, range in altitude, surface contours, thickness and structure of the drift, and the character of the outwash being considered. In connection with each morainic system the associated till plains are discussed, attention being given to the surface features and to the structure and thickness of the drift. In northern Illinois the several morainic systems are merged into a composite belt so complex that it is difficult to trace the individual members.

The several moraines and their associated sheets of till do not appear to be separated by intervals so wide as are found between the Illinoian and Iowan or the Iowan and Wisconsin drift sheets. Indeed, instances of the occurrence of a soil or a weathered zone between Wisconsin sheets are very rare. There may, however, have been considerable oscillation of the ice margin.

Chapter X. The late Wisconsin drift sheets. — The basis for separation from the early Wisconsin is first considered, after which the several morainic systems and their associated till plains are taken up in order as in the discussion of the early Wisconsin drift. An interpretation of the Kankakee sand area is attempted, though several questions connected with it still remain open. The chapter closes with a discussion of the striæ found within the limits both of the early and of the late Wisconsin drift.

Chapter XI. The Chicago outlet and beaches of Lake Chicago. — That a body of water once extended over the low districts bordering the southern end of Lake Michigan and discharged southwestward to the Des Plaines and thence into the Illinois River has been recognized since the early days of

settlement, and several papers discussing the beaches and the outlet have appeared. The latter has long been known as the Chicago outlet, because it led away from the site of that city. The lake has recently been given a name in harmony with that of the outlet (Lake Chicago).

After reviewing the previous reports and papers, the Chicago outlet is described in some detail. The several beaches of Lake Chicago are then taken up in order from highest to lowest. The chapter ends with a discussion of the present beach of Lake Michigan.

Chapter XII. Influence of the drift on drainage systems and drainage conditions.— It is shown that many drainage systems are entirely independent of the preglacial lines, while others are independent only in part, a considerable part of their courses being along the lines of old valleys. The development of drainage systems is shown to be much farther advanced on the Iowan and Illinoian drift sheets than on the Wisconsin. This is found to be due to differences in age, and not to natural advantages for discharge. The Wisconsin is, on the whole, more favored by uneven surface for the rapid development of drainage lines than the Illinoian. The several drainage systems are discussed in considerable detail.

Chapter XIII. Average thickness of the drift in Illinois.— Illinois affords an especially good opportunity for the estimate of the thickness of the drift, because of the large number of well sections obtained, and because of the comparative smoothness of the region. The inequalities of the rock surface beneath drift plains may be estimated by the study of neighboring driftless tracts, as well as by borings and outcrops within the drift-covered area. There are thus two quite different methods by which the average thickness of the drift may be ascertained.

The first method here used is that of averaging the results of borings and outcrops. These are averaged in each township in which the distance to rock is known, and the results are then combined for the average of all the explored townships. Consideration is then given to the distribution of the explored townships in reference to drift plains and moraines and to preglacial uplands and valleys, and necessary corrections are made. By this method the thickness of the drift is found to be not less than 100 feet, and it may be 120 feet or even more.

The second method, based upon a comparison of the Illinois drift area with the neighboring driftless tracts, gives 129.3 feet as the average thickness, or slightly more than the highest results obtained by the first method. Combining the two methods, the average thickness of the drift of Illinois can be placed at not more than 130 feet and not less than 100 feet.

An attempt is made to estimate the part contributed by each ice invasion, but the data prove to be scarcely complete enough for a good estimate. It is found that the general thickness within the limits of the Wisconsin drift is 40 to 45 feet greater than in the portion of the state outside.

Chapter XIV. The wells of Illinois.— This chapter aims to present all the reliable well records obtained within the state which throw light upon the deposits penetrated, as well as upon the character of the water supplies. In addition to the wells which terminate in the drift, there are included many which extend deeply into the underlying rock formations. This necessitates a classification of the underground waters and a description of the several rock formations penetrated, including a discussion of the attitude of the strata. The essential conditions for obtaining artesian wells are considered, and also the relation of the drift to the ordinary wells. There is a brief discussion of gas wells, confined mainly to those obtained in the drift. A tabulation of sources for city water supply is then presented, after which there appears a detailed discussion of wells, taken up by counties.

Chapter XV. Soils.—The sources of soil material are first discussed. An attempt is then made to classify the soils according to their origin. Eight classes are recognized as follows: Residuary soils, bowlder clays, soils, gravelly soils, sandy soils, bluff-loess soils, silts slowly pervious to water, fine silts nearly impervious, peaty or organic soils.

The matters of chief general interest will doubtless be found in the classification of the glacial series, in the changing configuration of the ice at its successive stages, in the differences of the deposits at the different stages, and in the estimate of the average thickness of the drift.

In the matter of classification, the monograph presents the latest and fullest expression of the conclusions toward which investigations in the interior have been steadily tending for the past decade. The classification offered is not regarded as final, either in the sense of including all the possible great divisions, or in the complete characterization of those recognized, but it clearly lies in the line of a true and ultimate classification. Fifteen stages are recognized, six of which are based upon notable glacial advances, five represent notable intervals of deglaciation, and four are based upon lacustrine stages after the beginning of the abandonment of the region by the last ice-sheet. The age of the oldest glacial formation is regarded as many times that of the latest; and the oldest interglacial intervals are also believed to be many times longer than the later ones. In a word, the oscillations appear to have been large in the earlier stages and to have grown less and less during the progress of the period. This newer view of the relative ages of the successive epochs, sustained as it appears to be by the progress of research in Europe, must be looked upon as one ofthe most important advances of recent years, for

it affects profoundly nearly all of the larger questions of glacial history.

The distinction between the ages of the several glacial sheets is founded upon careful estimates of the amounts of erosion they have respectively suffered, upon the depths and extent of the weathering process as exhibited alike in the clays and in the pebbles and bowlders, upon the degree of constructive mineralization in the form of segregates and general induration of the deposits, upon the extent of interglacial accumulations of soil, peat and similar deposits, and upon the nature of the life which occupied the region between the glacial stages, together with incidental criteria of more special nature and limited application. When it is considered that the broad sheet of Kansan till, which shows indubitable evidence of having been spread out as an approximately plane sheet, has been so thoroughly eroded over very large areas that only remnants of the original plane remain here and there, it is impossible for the candid mind to resist the conviction that it is very widely separated in age from the later drift-sheets which have been merely ditched by the water courses, leaving scattered over the broad, scarcely modified surfaces, multitudes of shallow basins which a few feet of cutting would completely drain.

While not new, the monograph brings out into sharp definition the lobate character of the ice margin at all of its stages. At the same time it shows that there was a change in the configuration of these lobes at different stages. It is perfectly clear from the general nature of these configurations that they are fundamentally dependent upon the topography of the region they occupy and of that which lies backward along the line of glacial invasion. At the same time there are some anomalies which, while not defiant of topography, do not clearly show their dependence upon it and indicate that other factors than topography were involved in determining the development of the ice lobes. These other agencies are very likely climatic, but they have not yet been deciphered. The most notable of these anomalies are the peculiar forms assumed by the Iowan drift and the shifting in the contours of the lobes between the earlier and later Wisconsin stages.

Closely allied to this variation in configuration is a remarkable variation in the mode of action of the ice at different stages to which the monograph contributes a large mass of data. The earlier drift-sheets

are spread widely over the country without evidences of profound abrasive action upon the pre-existing surface, not that such action was absent, but it was far less vigorous than in the later stages. In harmony with this milder action upon the face of the country invaded, the drift-sheet itself was spread much more uniformly than in later times and pronounced morainic ridges are much more rare, and when present are much feebler and less characteristic. At the same time, the glacial drainage appears to have been much less vigorous and in some instances surprisingly lacking in vigor. These phenomena are among the most suggestive that yet await causal explanation.

By far the most careful and trustworthy estimate of the average thickness of the drift which has heretofore been made in this country is embraced in chapter XIII of this monograph. Not only are the data much more ample and better distributed than those that have heretofore been at command, but they have been analytically classified and discussed by more critical methods. The most difficult element of the problem is the drift embraced in the preglacial valleys, the depth and configuration of which it is difficult to estimate. This has been attempted, however, along two different lines which give essential concordant results, and it is a fair presumption that the total estimate of the mass of the drift of the region investigated is a not distant approximation to the real facts. How far the territory of the Illinois glacial lobe is representative of the average thickness of the drift throughout the glaciated region cannot now be determined, for if the great Canadian tract be embraced, as it should, our knowledge is best defined by emphasizing its limitatations; but the average thickness in Illinois may rudely represent the average thickness for areas similarly situated near the border of the glaciated area, but even this cannot be confidently affirmed.

The work of Mr. Leverett is conspicuous for the judicial attitude of mind which eminently controls it. The emotional factor is held in marked abeyance and the intellectual factor suffers little trammeling from predilections. At the same time the large area covered by critical study testifies to an industry which could not have been greatly enhanced by emotional enthusiasm. The monograph will be best appreciated by those who are most familiar with the ground.—T. C. C.

Preliminary Report on the Copper-bearing Rocks of Douglas County, Wisconsin. By ULYSSES SHERMAN GRANT, Ph.D. Wisconsin Geological and Natural History Survey, Bulletin No. VI. Economic Series No. 3, pp. 55. 1900.

The report is the result of field work during the summer of 1899, and deals in a preliminary way with the St. Croix and Douglas copper ranges of Douglas county, Wisconsin. It contains four geological maps and several illustrative plates. Chapter I outlines the geology of the county and contains a sketch of the three rock series represented; namely, the Cambrian, the Upper Keweenawan, and the Lower Keweenawan. The Lower Keweenawan consists of igneous rocks, largely basic lava flows with a few interbedded conglomerates. The copper deposits are usually at or near the contacts of the flows, and the author has given some of the characteristics by which the contacts may be known. The Upper Keweenawan consists of conglomerates, sandstones and shales, lying apparently conformably upon the igneous beds and dipping southeast at low angles. The Lake Superior sandstone underlies the northern part of the county, and consists essentially of quartz sand, but in some places becomes conglomeratic, and in others clayey or shaly. Its junction with the Lower Keweenawan is marked by a fault of considerable displacement along which the traps are shattered. Chapter II describes some of the more important outcrops of the St. Croix range and chapter III treats the Douglas range in a similar manner.

The last chapter is a "brief discussion concerning the mode of occurrence of the copper, where to search for copper, and the value of the deposits." This chapter is of special value to the prospector and the investor. On pages 53 and 54 are given several analyses of copper-bearing rocks from the two ranges. R. D. GEORGE.

Upper and Lower Huronian in Ontario. By ARTHUR P. COLEMAN. Bulletin of the Geological Society of America, Vol. XI, pp. 107–114. 1900.

In his work as geologist for the Ontario Bureau of Mines the author has gathered much material bearing on the problem of the Huronian in Ontario. In tracing the Michipicoten iron range it was found that the band of siliceous rock associated with it, and generally resembling

sandstone, passes at times into cherty and jaspery and quartzitic facies. The same association of siliceous rock and iron ore is found near Pic River, near Rainy Lake and on Rainy River, and near Rat Portage. Jaspery material like that of Michipicoten is found interbedded with iron ores near Lakes Wahnapitae and Temagami, between Sudbury and the Ottawa River. "If, as seems probable, these jaspers are the equivalents of the western Huronian sandstones, we have a definite horizon, traceable from point to point across the whole northern end of the province" which will be "a most valuable thread with which to unravel the much disturbed and complicated series of Huronian in Ontario." The conglomerates frequently found near the iron-bearing series and containing sandstone, chert, or jasper, identical with those of the iron-bearing series, have a similar range from east to west across the province and are thought to mark the greatest break in the Huronian series, or, in other words, to form the basal conglomerate of the Upper Huronian.

The author shows that if these conclusions are well founded we have "a means of correlating the widely separated and very different looking rocks mapped as Huronian in Ontario. Applying these conclusions to the Shoal Lake district, a part of Lawson's Keewatin is of Huronian age. They may also lead to a more certain correlation of the pre-Cambrian rocks of Ontario and the Wisconsin-Minnesota region." R. D. GEORGE.

Mesozoic Fossils of the Yellowstone National Park. By T. W. STANTON. An extract from "Geology of the Yellowstone National Park," Monograph XXXII of the U. S. Geological Survey, Part II, Chapter XIII. Washington, 1899.

This chapter forms a valuable contribution to our knowledge of the Mesozoic faunas. The collection of invertebrate fossils described in it consists of seventy-eight species, having a distribution as follows: thirty-one are Cretaceous, forty-six are Jurassic, and one is possibly of Triassic age. The last specimen, a species of *Lingula* resembling *L. brevirostris* of Jurassic age, occurs in the Teton formation which occupies the stratigraphic position between the known Carboniferous and the undoubted Jurassic. This paleontologic evidence is considered too slight to form the basis of a correlation of the Teton with the Triassic of other areas.

The Jurassic assemblage forms the most important element of the collection. The two chief fossiliferous areas are: the one in the northwest corner of the Park, on the head waters of the Gardiner and Gallatin Rivers; and the other on the slopes of Sheridan Peak and farther southwest of Snake River. Two zones, characterized more by lithological than faunal peculiarities, are to be recognized, but the fossils belong to a single fauna.

The upper zone is marked by an arenaceous limestone yielding an abundance of *Rhynconella gnathophora*, *R. myrina*, *Ostrea strigilecula*, *Camptonectes bellistriatus*, and *C. pertenuistriatus*. The lower zone is characterized by calcareous clays and marls containing the majority of the above forms associated with *Pleuromya subcompressa*, *Pholadomya kingi*, and *Gryphea calceola* var. *nebrascensis*.

I found very similar zones in the Freeze-Out Hills of Wyoming, but they were characterized by slightly different assemblages of fossils. The upper zone consisted of clays and arenaceous limestones containing *Pentacrinus astericus* in abundance, and *Asterias dubium*, *Camptonectes bellistriatus*, *C.* (*extenuatus*) *pertenuistratus*, and *Ostrea strigilecula*. In the lower zone occurred clays and marls with calcareous nodules yielding *Astarte packardi*, *Pinna kingi*, *Pleuromya subcompressa*, *Pholadomya kingi*, and other forms. *Belemnites densus* and *Pentacrinus astericus* is common to both zones.

As these zones are both extremely narrow, are composed largely of clastic material, and contain an assemblage of fossils in many instances common to both, I think the conclusion that but a single fauna is represented is the correct one. This conclusion in regard to the Yellowstone region Dr. Stanton extends to the entire Jurassic formation of the Rocky Mountain region, and concludes as follows: "The stratigraphic relations and the geographic distribution of the marine Jurassic of the Rocky Mountain region are in favor of the idea that all of these deposits were made contemporaneously in a single sea."

A thin stratum of limestone in a position above the Jurassic beds and not far below the base of the Cretaceous section contains fresh water gastropods and Unios. The formation which contains this limestone is referred with considerable doubt to the Dakota. It is thought that it may be the equivalent of the Kootenai or Como. A similar limestone stratum occupying approximately the same stratigraphic position is found in the Como of Wind River, of the Black Hills, and the writer found it also in the Freeze-Out Hills. In all these localities

it contains a fresh water fauna consisting of gastropods and Unios, and in some instances species common to two or more localities.

The Colorado formation is represented by a characteristic fauna, consisting for the most part of Inocerami. The Montana formation is recognized, but its divisions are not easily differentiated. It seems probable that only the lower part of the Montana is represented.

In all, thirteen new species are figured and described. The majority of these belong to the Jurassic.

W. N. LOGAN.

The Glacial Gravels of Maine and their Associated Deposits. By GEORGE H. STONE. Monograph XXXIV, U. S. Geological Survey, 499 pp., 52 plates, 36 figures. Washington, 1899.

The enthusiastic pursuit of kames and eskers through the forests of Maine without official aid, in the later seventies, by Professor Stone, led to his engagement for a monographic study of all the glacial gravels of that phenomenally rich region by the U. S. Geological Survey. The results appear in this monograph. It would be an error, however, to overlook the second half of the title, for much attention is given to the formations associated with the glacial gravels, and tributary to their formation, so that the volume falls little short of being a monograph on the Pleistocene deposits of Maine.

So far as present knowledge extends, two regions surpass all others in the richness of their esker or osar phenomena — Maine on this continent, and Sweden on the eastern. This singular distribution is perhaps due to a critical relation between the general slope of the land surface in these regions and the minimum gradient at which glacier ice flows effectively, so that a condition of approximate stagnation was assumed in the closing stages of glaciation and the internal drainage lines of the ice sheet were permitted to develop with exceptional facility. However that may be, Maine is certain to be the classic field for esker studies in this country.

The plan of the volume embraces a preliminary discussion in which the fundamental facts of surface geology as illustrated in Maine are set forth with considerable fullness (chapters I, II, and III). The operative agencies are discussed in close connection with the phenomena described. This is followed by a general description of the systems of glacial gravels (chapters IV, and V). By systems is to be understood

those connected series of gravel ridges that are interpreted as the products of individual drainage systems of the ice sheet, the products of each river system being a gravel system. Some forty odd systems of this kind are recognized besides several less defined series and numerous branches and individual eskers, making on the whole a most phenomenal record of glacial drainage. The description of these occupies 170 pages.

The classification of the gravels and associated deposits and a discussion of their genesis follows and constitutes essentially the remainder of the volume (chapters v and vi, 224 pages). The discussion of the genetic element is elaborate and detailed. Something of the range of special subjects may be gathered from the following special themes: Quantity of englacial débris; distinction between englacial and subglacial tills; the origin of drumlins; the relations of the marine gravels; bowlder fields and bowlder trains; single or multiple glaciation in Maine; the relation of the glacial waters to the glacial sediments; the sizes of the glacial rivers of Maine; the zones of the Maine ice sheet; englacial streams; the directions of subglacial and englacial streams under existing glaciers; the internal temperatures of ice sheets; the basal waters of ice sheets; basal furrows as stream tunnels; the genesis and maintenance of subglacial and englacial channels; the forms of glacial channels; extraordinary enlargements of glacial river channels; the directions of glacial rivers compared with the flow of ice; the relations of glacial rivers to the relief forms of the land; sedimentation in places favorable or unfavorable to the formation of crevasses; glacial potholes; the formation of kames and osars; the bowlders of the glacial gravels; comparative studies on the glaciation of the Rocky Mountains and on the glaciers of Alaska; the modification of the glacial gravels by the sea; the short isolated osars or eskers; the hillside osars or eskers; the isolated kames or eskers ending in marine deltas; isolated osar-mounds not ending in marine deltas; the disconnected osars; the relations of glacial gravels to the fossiliferous marine beds; retreatal phenomena of the ice; causes of non-continuous sedimentation within the ice channels; the continuous osars and their comparison with discontinuous osars; were osars formed by subglacial or superglacial streams? tests of subglacial and superglacial depositions; special features and their explanation.

The illustrations are numerous and add greatly to the value of the text, and the large list of maps set forth the remarkable distribution of the gravel systems.

The work is characterized by enthusiasm and a pervasive desire to explain in fullness and detail all of the phenomena presented. The observational and the rational go hand in hand and each lends interest to the other.

T. C. C.

Lower Cambrian Terrane in the Atlantic Province. By C. D. WALCOTT, Proceedings of the Washington Academy of Sciences. Vol. I, pp. 301–339. February 14, 1900.

The object of the paper, as stated by the author, is to show the stratigraphic relations and successions of the Cambrian faunas of the Atlantic province. In the author's correlation paper on the Cambrian (Bull. 81, U. S. Geol. Surv. 1891), reference is made to unsolved problems of the Cambrian of this province. Mr. G. F. Matthew's study of these problems has led him to conclusions not in accord with those tentatively set forward by Mr. Walcott. He finds the Etcheminian beds at Hanford Brook unconformably below the Protolenus zone and regards them as a pre-Cambrian Paleozoic terrane, and makes a twofold division of the Cambrian of the Atlantic province as follows:

Upper Cambrian, - - -	Dictyonema fauna. Peltura fauna. Olenus fauna.
Lower Cambrian, - - -	Paradoxides fauna. Newfoundland species described. Protolenus fauna.

Mr. Walcott, having made a careful study of the Hanford Brook and other localities cited by Mr. Matthew in support of his position, notes the absence of Etcheminian débris in the overlying St. John quartzite, the absence of an irregularly eroded surface on the Etcheminian beds, and the evidence of overlap of these beds on the subjacent Algonkian, and holds that the patchiness and variation in thickness of the Etcheminian may be the result of deposition of sediments upon a very irregular sea-bottom, and not of erosion as held by Mr. Matthew. Mr. Walcott believes the distinctive features of the Etcheminian fauna pointed out by Mr. Matthew do not necessarily separate it from the

Lower Cambrian. The paper closes with the following conclusions:

"(*a*) The 'Etcheminian' terrane of Matthew is of Lower Cambrian age.

"(*b*) The Olenellus fauna is older than the Paradoxides and Protelenus fauna of the Middle Cambrian.

"(*c*) The Cambrian section of the Atlantic Province of North America includes the Lower, Middle, and Upper Cambrian divisions as defined by me in 1891."

R. D. GEORGE.

Forest Reserves. Part V of the Nineteenth Annual Report of the United States Geological Survey. HENRY GANNETT, Chief of Division, Washington, D. C., 1899.

This report consists of the following parts: The forests of the United States, by Henry Gannett; Black Hills Forest Reserve, by H. S. Graves; Big Horn Forest Reserve, by F. E. Town; Teton Forest Reserve, from notes by F. S. Brandegee; Yellowstone Park Forest Reserve, from notes by F. S. Brandegee; Priest River Forest Reserve, by J. B. Leiberg; Bitterroot Forest Reserve, by J. B. Leiberg; Washington Forest Reserve, by H. B. Ayers; Eastern Part of Washington Forest Reserve, by M. W. Gorman; San Jacinto Forest Reserve, by J. B. Leiberg; San Bernardino Forest Reserve, by J. B. Leiberg; San Gabriel Forest Reserve, by J. B. Leiberg: Forest conditions of Northern Idaho, by J. B. Leiberg; Pine Ridge Timber, Nebraska, by N. H. Darton.

According to the report there are in the United States, exclusive of Alaska, 1,094,496 sq. miles of wooded land, or in other words 37 per. cent of the total area is wooded. The total value of the forest product of the country for 1890 was 800 million dollars which is an amount slightly in excess of its mineral production. The total amount of sawed lumber consumed was 23,500 million feet B. M., and the amount used for fuel was 180,000 million feet B. M.

The sources of injury to forests are classed under the categories of fires, winds, lightning, insects, and wasteful methods of lumbering. The necessity for better forest management is urged in order to prevent waste, and to establish forests in the place of those being depleted for legitimate purposes. It is urged that the object of forest management should be to produce forest products in as short a time

as possible, to establish if possible a system of forestry which will produce lumber timber in less than 150 years, and mine timber in less than 100 years.

The principal subjects discussed in the several divisions of the report embrace the topography, the limits, the agricultural lands, the mining and the forests of the reserves. Other topics include the water supply, parks species of timber, classification of timber, amount of available timber, and means of transportation of lumber.

The report is furnished with an excellent set of illustrations and maps. It is a valuable contribution, well calculated to accomplish the purposes for which it was written, *i. e.*, to furnish as full data as possible concerning our forests, and to waken a desire for their preservation.

W. N. LOGAN.

Geology of Narragansett Basin. By N. S. SHALER, J. B. WOODWORTH and A. F. FOERSTE. Monograph XXXIII, U. S. Geological Survey, pp. xx + 394. 1900.

The Monograph is divided into: Part I, General Geology of the Narragansett Basin, by N. S. Shaler; Part II, Geology of the Northern and Eastern Portions of the Narragansett Basin, by J. B. Woodworth, and Part III, Geology of the Carboniferous Strata of the Southwestern Portion of the Narragansett Basin, with an account of the Cambrian deposits, by Aug. F. Foerste.

The stratified rocks of the basin range from Cambrian to Carboniferous. The structure of the basin makes it appear probable that it originally contained an extensive development of pre-Cambrian rocks. Upon these were laid down the lowest Cambrian beds. The Middle Cambrian is not represented in the region south of Braintree. The Upper Cambrian is represented only by pebbles of quartzite in the conglomerates. While only the Lower Cambrian is found in situ, pebbles of Middle and especially of Upper Cambrian are so abundant as to lead to the statement that "there appears to have been nearly continuous deposition in this field throughout the Cambrian period." The Silurian and Devonian do not appear to be represented in the Narragansett Basin. Upon the Cambrian strata and the eruptive granites come the Carboniferous strata which occupy the greater part of the basin. It is probable that the earliest Carboniferous rocks of the basin are the upper part of the Coal Measures, and it is possible that the upper conglomerates of the basin may be Permian. The basin was probably

partly formed before Carboniferous time. Professor Shaler believes that east of the Appalachians there were developed during Carboniferous times a great series of erosion troughs which by sedimentation and subsidence became centers of quaquaversal orogenic movement, resulting in foldings with axes variously inclined to one another within the same trough. The truncated remains of the folds so produced are to be seen at various points along the Atlantic seaboard. That these erosion troughs were river valleys and estuaries is suggested by their lack of parallel or other definite arrangement such as is seen in the Appalachians, as well as by the character of the deposits they contain. The Narragansett basin is one of these ancient erosion troughs in which the folds were of the anticlinal and synclinal type. The present average structural depth of the basin is placed at 7000 feet, but it is assumed that this depth is due mainly to folding resulting from accumulation of deposits. The source of the bulk of the sediments of the basin was the immediately surrounding granitic, trappean, schistose and other rocks. There are also many quartzitic pebbles of Cambrian age in the conglomerates but the source of the similar pebbles of the drift is considered unsettled. In discussing the glacial history of the region Professor Shaler expresses the view that this district was one of extensive and long continued glaciation during the Carboniferous period and that the important features of the upper stratified rocks are due to glacial action.

In the economic section the soils, coals, and iron ores are discussed at considerable length. Recent subsidence in the immediate vicinity of the basin has caused flooding of old valleys. This and the thick covering of drift have rendered geological work difficult, and the delimitation of formations uncertain. The volume represents much detailed work accomplished in a region presenting more than ordinary difficulties. There are many well placed plates and figures to illustrate the text.

R. D. GEORGE.

On the Lower Silurian (Trenton) Fauna of Baffin Land. By CHARLES SCHUCHERT. Proceedings of the U. S. National Museum. Vol. XXII, pp. 143–177, with plates XII to XIV.

At the request of the author, Mr. J. N. Carpender and others (who accompanied the Seventh Peary Arctic Expedition as far as Baffin Land in 1897,) made collections of fossils from Silliman's Fossil Mount at

the head of Frobisher Bay. The fossils are well preserved and many of them are now in the U. S. National Museum. The paper gives a brief summary of the geology of the region as gathered from reports by those who have either visited it or have examined collections from it. The Lower Silurian fossils so far collected are of Trenton and Utica age, and strata containing these faunas are widespread in eastern Arctic America. So far as known they rest upon the pre-Cambrian rocks and are overlain by beds of Niagara age. Of the 72 species known from the locality of Silliman's Fossil Mount 28 are restricted to it. Of the remaining 54 species, 41 are found in the Manitoba-Minnesota-Wisconsin region and 17 in the New York-Ottawa region. A comparison of the 54 species found elsewhere with those from definite stages in Minnesota shows that 10 are found in the Birds-eye (Lowville), 17 in the Black River, 38 in the Galena, and 11 in the Cincinnatian.

The close resemblance of the Minnesota Galena to the Silliman's Fossil Mount formation may in large part explain the close identity of the faunas. In the summary, page 175, the author says: "The Baffin Land fauna had an early introduction of Upper Silurian genera in the corals Halysites, Lyella and Plasmopora. In Manitoba similar conditions occur in the presence of Halysites, Favosites, and Diphyphyllum. The Trenton fauna of Baffin Land shows that corals, brachiopods, gastropods, and trilobites have wide distribution and are therefore less sensitive to differing habitats apt to occur in widely separated regions. On the other hand the cephalopods and particularly the pelecypods, indicate a shorter geographical range. The almost complete absence of Bryozoa in the Baffin Land Trenton contrasts strongly with the great development of these animals in Minnesota and elsewhere in the United States."

The paper is a valuable addition to our knowledge of the Ordovician faunas of eastern Arctic America.

R. D. GEORGE.

The Freshwater Tertiary Formations of the Rocky Mountain Region. By W. M. DAVIS. Proceedings of the American Academy of Arts and Sciences, Vol. XXXV, No. 17, March, 1900.

In this very timely paper Professor Davis gives voice to a growing change of opinion regarding the specific mode of origin of the most

characteristic class of formations of the Rocky Mountain Tertiaries. During recent years not a few geologists, here and there, have expressed a disposition to regard some of the deposits usually assigned to lakes as the products of stream action or "sheet wash," or of a combination of these with lake deposition. To the reviewer, who is among these dissenters, the favorite illustration of such modes of deposition is the present and recent accumulation in the Great Valley of California where several forms of subaërial aggradation are conjoined with lacustrine and marine deposition. This newer mode of interpretation has been applied to a notable series of formations distributed at intervals from the Medina, and even the Keweenawan, to the Lafayette and the recent deposits of the great basins of all the continents, particularly the arid basins. The great red terranes, with their associated products of desiccation and saline concentration, especially, have seemed to the reviewer attributable to such combined action, since a basin of saline concentration carries in its very terms the idea of a basin of detrital lodgment whose central part may be an area of subaqueous deposition but whose border is almost inevitably a zone of subaërial accumulation. The doctrine of non-lacustrine basin-aggradation, as it lies in the mind of the reviewer, has its most distinctive application to tracts of relative aridity, for it is in these, chiefly, that the conditions of subaërial lodgment preponderate over the conditions of subaqueous deposition, except in the case of aggrading river bottoms near base level which are undergoing a depression of gradient by deformation. In an arid basin-tract the precipitation is likely to be greatest on the elevated rim, and there it is often spasmodic, taking the form of cloudbursts and similar intensified forms. The gradient is also highest, as a rule, in the rim zone. These form a combination of agencies which result in an exceptional transportation of detritus down the slopes of the basin rim followed by a marked reduction of power of transportation as the flatter part of the basin is reached; for there the flood loses its power by lowered gradient, by spreading, by absorption, and by evaporation. Deposition is the usual consequence. In a humid region, the conditions are largely reversed; the streams augment in volume as they flow over the basin-plain and the power of transportation is more or less fully maintained. If the basin be a closed one the accumulated waters arising from the excess of precipitation over evaporation soon cover the basin floor with a lake which occupies the territory that in an arid region would be

covered in large part with subaërial detritus. In a humid region with free drainage no great thickness of detritus can usually be built up on the floor of a basin without increasing the gradient so as to suspend the process of aggradation, unless movements of deformation or changes of sea-relationship intervene to renew and perpetuate the conditions of aggradation. This of course may happen, but it is rather to be classed as an accidental intervention than as a systematic process.

The presumptions therefore seem to lie on the side of lacustrine deposition, with incidental fluvial aggradation, in humid regions, while in arid regions they lie on the side of fluvial aggradation, with incidental lacustrine deposition. To the reviewer, therefore, the question has a specific climatic relationship and this relationship seems much the most important phase of the subject. Given the same humidity, and the ratio of lacustrine to fluvial deposition is dependent on surface adjustments of a local nature. Given the same surface adjustments, and the ratio of lacustrine to fluvial deposition is dependent on states of humidity or aridity. But the humidity or the aridity of an area large enough to have geological importance, implies atmospheric states that are a function of the whole atmosphere, and of its modes of circulation, and hence has far-reaching significance.

If these considerations have any validity, the question which Professor Davis pointedly raises regarding the Rocky Mountain Tertiaries, as a specific example of the class under question, deserves the most critical attention. The value of an academic discussion, which is often unwisely underrated by the working field geologist, lies chiefly in deploying the problem and laying the groundwork for discriminative observations. Professor Davis seems to be altogether correct in pointing out a lack of critical observation and interpretation in most previous studies of the Tertiaries in question, and his discussion can hardly fail to call forth incisive studies upon these formations. Obviously their true character can only be determined by such critical field studies. A first step is the establishment of criteria of discrimination between lacustrine and fluvial deposits; by no means an easy task where the products of relatively shallow lakes are to be distinguished from those of rivers, which is really the critical case. It is not clear that the criteria given in the paper will always hold good, but there are several additional ones that may be brought into service, such as the distribution of the remains of land animals in the midst of

the basin, the occurrence of marsh-formed or land-formed lignites in similar situations, the interstratification of beds of gypsum or other desiccation products, and analogous criteria that imply aërial conditions. T. C. C.

The Crystal Falls Iron-Bearing District of Michigan. By J. MORGAN CLEMENTS and HENRY LLOYD SMYTH, with a chapter on the Sturgeon River Tongue by William Shirley Bayley and an Introduction by Charles Richard Van Hise. U. S. Geological Survey. Monograph XXXVI. Washington, 1899.

This report is the third in a series of four monographs on the iron-bearing district of the Lake Superior Region. Two having been published previously: one on the Penokee district (Monograph XIX). The other on the Marquette district (Monograph XXVIII). The fourth, on the Menominee district, is to follow.

The Crystal Falls district was divided areally, the western half being studied by Mr. Clements and the eastern half by Mr. Smyth, and the Sturgeon River Tongue by Mr. Bayley. The investigation was conducted under the charge of Mr. Van Hise, who sums up the general results in an introductory chapter. The district embraces 840 square miles. As pointed out in the introduction the rocks belong to the Archean and Algonkian. The latter consisting of a Lower Huronian and an Upper Huronian separated by unconformity. The Archean is believed to be wholly igneous in origin, it occupies a broad area in the eastern part of the district and has not been closely investigated. Several smaller areas occur within parts of the region carefully studied. Owing to the readily decomposable nature of the rocks in places and to the drift mantle the detail character of the formations is unknown for part of the area described by Clements, and in the belt worked by Smyth the rock surface is almost wholly concealed by glacial deposits and vegetation. It will be seen under what adverse circumstances the field work was carried forward, and how much credit is due the geologists who have brought to light so much valuable information from so unpromising a region.

The Lower Huronian consists of quartzite, dolomite, slate, a volcanic formation, and some schists. The series has a minimum thickness of 2200, and a possible maximum thickness of 16000 feet. The sediments probably nowhere exceed 5000 feet in thickness. The Upper Huronian

is a great slate and schist series, not separable into individual formations, and whose thickness cannot be approximately estimated. All of these formations have been cut by igneous rocks of various kinds and at different epochs.

Metamorphism has greatly altered the character of the Algonkian rocks. In the Lower Huronian the quartzite is the altered form of a sandstone and conglomerate in which the pebbles have been nearly destroyed. It is in places schistose. The dolomite is a nonclastic sediment. The slate or schist is an altered mudstone. The volcanic formation is perhaps the most characteristic feature of the Crystal Falls district. It occupies a larger area than the other Lower Huronian formations and consists of basic and acid rocks, lavas and tuffs, with subordinate interbedded sedimentary rocks. The iron-bearing formation, called the Groveland, consists of sideritic rocks, cherts, jaspillites, iron ores, and other varieties characteristic of the iron-bearing formations of the Lake Superior region.

After elevation and unequal erosion of the Lower Huronian, conditions of deposition covered these formations with sandstone and slate conglomerate, passing upwards into shales and grits, subsequently altered to mica-slates and mica-schists. These were followed by combined clastic and non-clastic sediments, the latter including iron-bearing carbonates. Above these is a great thickness of mica-slates and mica-schists.

After a long period of deposition a profound physical revolution occurred, raising the region and folding it in a most complex manner. The folds have steep pitches indicating great compressive stresses in all directions tangential to the surface of the earth. Subsequent to or during the late stage of this time of folding there was a period of great igneous activity, probably contemporaneous with the Keweenawan, intruding within the rocks vast bosses and numerous dikes of peridotites, gabbros, dolerites and granites. These intrusives, while altered by metasomatic changes, do not show marked evidence of dynamic metamorphism.

Subsequently the region was subjected to great denudation and reduced approximately to its present configuration. In late Cambrian time Upper Cambrian sediments were deposited upon it. Whatever may have been deposited upon the Cambrian has been removed by erosion together with most of the Cambrian. If the region was again submerged in Cretaceous times no evidence of the fact remains.

During the Pleistocene period a thick mantle of glacial deposits was spread over the entire area, which has been eroded far enough to uncover the rocks here and there.

Clements's description of the western part of the district treats of the surface features, the economic resources and the petrographical character of the various formations, especial attention being paid to the volcanic rocks. The great abundance of volcanic breccias and tuffs indicates the probable existence in Huronian time of a volcanic cone in this region, but the possible location of its vent has not been discovered. A small part of the igneous rocks are acid, their area being too small to map on the scale of publication. They include rhyolite-porphyries and aporhyolite-porphyries and breccia of the latter. The great part of the volcanics are metabasalts and breccias of the same. An interesting development of ellipsoidal structure is noted. The pre-Cambrian intrusive rocks include granites and rhyolite-poryhyry, metadolerite, meta-basalt and picrite-porphyry, besides a series considered to be closely connected genetically ranging from granite, tonalite and quartz-mica-diorite through diorite, gabbro, and norite to peridotite. The diorite is closely related to monzonite.

In the second part of the monograph Smyth discusses at length the effect of buried magnetic ores on the magnetic dip needle, describes its use and the results of careful observations in locating the iron-bearing deposits. He also describes the different formations structurally and petrographically. The same is done by Bayley for the Sturgeon River Tongue. J. P. I.

The Geography of Chicago and its Environs. By ROLLIN D. SALISBURY and WILLIAM C. ALDEN. Bulletin No. 1 of the Geographic Society of Chicago, published by the Society. Chicago, 1899. 64 pp.

This pamphlet is a model essay on local geography written in an interesting style and illustrated in an attractive and instructive manner. From the maps and descriptions it is learned that Chicago is situated on a plain which stretches from Winnetka, sixteen miles north, to Dyer, about twenty-eight miles south of Chicago, and sweeps eastward around the southern end of Lake Michigan. This plain is narrower at its extremities and has a maximum width of fifteen miles in about the latitude of Chicago; it is limited on the east and northeast by Lake

Michigan, on the west and southwest generally by the Valparaiso moraine which loops around the southern end of Lake Michigan, through northern Indiana into Michigan. The plain topography is varied by three prominent "islands:" Stony Island, a drift-covered, dome-shaped hill of Niagara limestone with quaquaversal dip; Blue Island, a single morainic ridge about six miles long and fifty feet above its surroundings; and Mt. Forest Island, a portion of the Valparaiso moraine about 120 feet higher than the plain, separated from the rest of this moraine by the Chicago outlet. The plain is continued through the Valparaiso moraine southwest of Chicago by the Chicago outlet, which is divided by Mt. Forest Island into the Sag outlet and the Des Plaines outlet. The Des Plaines outlet is now followed by the Chicago Drainage Canal. Several less conspicuous gravel and sand beach ridges converging toward the Chicago outlet from the northeast and southeast help to break the monotony of the plain. On these ridges are oak groves, which have apparently suggested the names for the towns Oak Park, Oak Lawn, Englewood and others. The eastern third of the plain is largely made of gravel and sand. With the exception of the beach ridges, the western two thirds is largely of till. These deposits vary in depth from 0 to 130 feet. The country rock is Niagara limestone which has an elevation varying from 124 feet below the lake level to about 20 feet above it in Stony Island, and 100 to 110 feet above it under the Valparaiso moraine. The southeastern edge of the plain is occupied by a series of small lakes, the basins of which are in large part made by enclosing beach ridges. At the south end of Lake Michigan there are sand dunes with a maximum height of 100 to 200 feet. Other smaller dune areas exist nearer the city.

The main recorded events in the geographical history of the region since Devonian times are: (1) Withdrawal of the sea and destruction of formations younger than the Niagara with the exception of some fossiliferous Devonian material preserved in joints of the Niagara formation; (2) invasion of the ice in the glacial period, rounding off the angularities of the rock surface and probably diminishing the relief of the region by deposits of drift. At a late stage of the ice invasion the Valparaiso moraine was made. (3) As the ice edge retreated from the Valparaiso moraine a lake accumulated in the depression between the ice front and the moraine until the water stood at an elevation sixty feet above the present Lake Michigan when it overflowed to the west through the valley of the Des Plaines River and through the Sag outlet. To

this lake Mr. Leverett has given the name Lake Chicago. The stages in the history of this lake are as follows:

(*a*) Glenwood stage, the highest stage, when the level was sixty feet higher than Lake Michigan is now. During this stage the outlet was cut down twenty feet.

(*b*) A stage of recession, when discharge through the Chicago outlet ceased and the water withdrew from the Chicago plain in part or entirely. During this stage deposits of peat accumulated.

(*c*) Calumet stage, in which the water again discharged through the Chicago outlet at a level forty feet higher than the present level of Lake Michigan. During this stage the Calumet beach was formed over the peat deposits of the preceding stage.

(*d*) The lowering of the outlet gradually reduced the level of the lake twenty feet when the Tolleston beach was formed.

(*e*) A lower outlet was opened to the north and the lake fell below the level of the Chicago outlet. This closed the history of Lake Chicago and inaugurated that of Lake Michigan. Between the Tolleston beach and the shore of Lake Michigan there is an extensive series of sand and gravel ridges among which lie the small lakes mentioned above.

Abundant evidence of fresh water life has been found in the deposits of the Tolleston stage of the lake, but not in the deposits of earlier stages. On the surface of the Calumet beach, however, marine shells of southern species have been found, which may have been introduced artificially.

The bulletin is essentially a popularized version of the work of the United States Geological Survey and is a tribute to the value of its investigations. It is to be hoped that this bulletin will stimulate the publication of similar essays on local geography elsewhere. Interest in geography is certainly increased by such publications.

CHARLES EMERSON PEET.

Recent Publications

—Alabama, Geological Survey of. Report on the Warrior Coal Basin. With fifty figures in text, seven plates and one map. By Henry McCalley, Assistant State Geologist.

—Agassiz, Alexander. Explorations of the "Albatross" in the Pacific. Reprinted from the American Journal of Science, Vol. IX, January, February, March, and May numbers.

—Agriculture, Department of. Yearbook for 1899. Washington, D. C.

—Bennett, C. W. Coldwater, Mich. The Ice Age and What Caused It. Published serially in the Michigan Miner, May-June 1900.

—Darton, Nelson H. Preliminary Report on Artesian Waters of a Portion of the Dakotas. Extract from Seventeenth Annual Report of the U. S. Geological Survey, 1895-6, Part II, Economic Geology and Hydrography. Washington, 1896.

—Emerson, Benjamin K. The Tetrahedral Earth and the Zone of the Intercontinental Seas. Annual Presidential Address. With an Appendix. The Asymmetry of the Northern Hemisphere. Bulletin Geological Society of America, Vol. II, pp. 61–106. Pls. 9–14. Rochester, March 1900.

—Grabau, Amadeus W. Siluro-Devonic Aspect in Erie County, New York. Bulletin Geol. Soc. of Amer., Vol. XI, pp. 347–376. Pls. 21–22. Rochester, May 1900.

—Gulliver, F. P. Vienna as a Type City. Reprinted from the Journal of School Geography, Vol. IV, No. 5, May 1900. Thames River Terraces in Connecticut. Bull. Geol. Soc. Am., Vol. X, No. 898.

—Hay, O. P. Descriptions of Some Vertebrates of the Carboniferous Age. Reprinted from Proc. Amer. Philos. Soc., Vol. XXXIX, No. 161.

—Hayford, John F. Inspector of Geodetic Work, U. S. Coast and Geodetic Survey. The Transcontinental Triangulation under the 39th Parallel. Bull. University of Wisconsin, No. 38, Engineering Series, Vol. II, No. 5, pp. 173–194. Pls. 1–5. Madison, June 1900.

—Haworth, Erasmus. Relations between the Ozark Uplift and Ore Deposits. Bull. Geol. Soc. Amer., Vol. XI, pp. 231–240.

—Indiana, Department of Geology and Natural Resources, 24th Annual Report, 1899. Indianapolis.

—KNIGHT, WILBUR C. The Jurassic Rocks of Southeastern Wyoming. Bull. Geol. Soc. Amer., Vol. XI, pp. 377–388. Pls. 23. Rochester, May 1900.

—Louisiana, Geological Survey of. A Preliminary Report on the Geology of Louisiana. Geology and Agriculture, Part V. By Gilbert D. Harris, Geologist in Charge, and A. C. Veatch, Assistant Geologist. Report for 1899. State Experiment Station, Baton Rouge, La.

—PACKARD, ALPHEUS S. View of the Carboniferous Fauna of the Narragansett Basin. Proc. of the Am. Acad. of Arts and Sciences, Vol. XXXV, No. 20, April 1900.

—United States Geological Survey:

Nineteenth Annual Report, 1897–8, Part II. Papers chiefly of a Theoretic Nature. Part III, Economic Geology. Part V, Forest Reserves, Atlas accompanying.

Twentieth Annual Report, 1898–9, Part I, Director's Report, Trianguation and Spirit Leveling. Part VI, Mineral Resources of the United States, 1898. Metallic Products and Coke. Part VI continued, Mineral Resources of the United States, 1898, Non-Metallic Products except Coal and Coke.

Monograph XXXII, Part II, Geology of the Yellowstone National Park. Descriptive Geology, Petrography, and Paleontology. Hague, Iddings, Walcott, Stanton, Weed, Girty, Knowlton.

Monograph XXXIII, Geology of the Narragansett Basin. Shaler, Woodworth, Foerste.

Monograph XXXIV, Glacial Gravels of Maine and other Associated Pleistocene Deposits. Stone.

Monograph XXXVI, The Crystal Falls Iron-Bearing District of Michigan, with chapter on the Sturgeon River Tongue. Clements, Smyth, Bayley, Van Hise.

Monograph XXXVII, Fossil Flora of the Lower Coal Measures of Missouri. White.

Monograph XXXVIII, The Illinois Glacial Lobe. Leverett.

—YAHE, H. The Brachiopod Lyttonia from Rikuzen Province. Reprinted from the Journal of the Geological Society, Tōkyo, Vol. VII, No. 79, Japan, April 1900.

A Geological Section of the Nebraska Permian from Beatrice South and East to the Kansas Line.

[To be inserted between pp. 356 and 357, May–June number, 1899.]

LIMESTONE QUARRY ABOVE FLORENCE FLINT. BLUE SPRINGS, NEB.

EXPOSURE OF FLORENCE FLINT IN A QUARRY EAST OF WYMORE, NEB.